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RESEARCH MEMORANDUM

EFFECTS OF EXTERNAL STORES ON THE STATIC LONGITUDINAL AND LATERAL AERODYNAMIC CHARACTERISTICS OF A MODEL OF A 45° SWEPT-WING FIGHTER AIRPLANE AT MACH NUMBERS OF 1.61 AND 2.01

By Gerald V. Foster and Cornelius Driver

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NATIONAL ADVISORY COMMITTEE
FOR AERONAUTICS
WASHINGTON
August 23, 1956

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EFFECTS OF EXTERNAL STORES ON THE STATIC LONGITUDINAL AND LATERAL AERODYNAMIC CHARACTERISTICS OF A MODEL OF A 45° SWEPT-WING FIGHTER AIRPLANE AT MACH NUMBERS OF 1.61 AND 2.01

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SUMMARY

An investigation has been conducted in the Langley 4- by 4-foot supersonic pressure tunnel to determine the effects of various external-store configurations on the longitudinal and lateral aerodynamic characteristics of a model of a 45° swept-wing fighter airplane. Pylon-mounted stores located at 23.8, 46.2, and 67.0 percent of the wing semispan were tested individually and in various combinations. The inboard stores relative to outboard stores were similar in shape but approximately 25 percent greater in size. The stores located at 46.2 percent of the wing semispan represented a large fuel tank and had an unsymmetrical shape.

The addition of all stores resulted in an increase in drag coefficient of the model at zero lift coefficient from 0.038 to 0.057 at a Mach number of 1.61. All stores with the exception of the outboard stores resulted in small positive trim change in the pitching-moment characteristics. The inboard stores and those combinations of stores including the inboard stores resulted in a decrease in directional stability at both Mach numbers. This is associated with the adverse effect of the stores on the vertical tail.

INTRODUCTION

An investigation has been conducted in the Langley 4- by 4-foot supersonic pressure tunnel to determine the aerodynamic characteristics of a model of a 45° swept-wing fighter airplane through a range of Mach numbers from 1.41 to 2.01. Reference 1 presents results of the investigation pertaining to the static longitudinal stability and control characteristics of the model. Reference 2 presents the lateral and directional stability characteristics of the model.

The present paper contains results showing the effects of various arrangements of external stores on the aerodynamic characteristics of the model in pitch and sideslip for Mach numbers of 1.61 and 2.01. In order to expedite the issuance of this information, only a brief analysis had been made of these data.

COEFFICIENTS AND SYMBOLS

The force and moment data have been reduced to coefficient form. The lift, drag, and pitching moments are referred to the stability-axis system; whereas, the lateral force, rolling moment, and yawing moment are referred to the body-axis system with the reference center of gravity at a fuselage longitudinal station corresponding to the 37.5-percent point of the wing mean geometric chord. (See figs. 1 and 2.) The coefficients and symbols are as follows:

C_L	lift coefficient, F_L/qS
C_D'	longitudinal-force coefficient, F_D'/qS
C_m	pitching-moment coefficient, $M_Y/qS\bar{c}$
C_Y	lateral-force coefficient, F_Y/qS
C_l	rolling-moment coefficient, M_X/qSb
C_n	yawing-moment coefficient, M_Z/qSb
F_D'	drag, lb
F_L	lift, lb
F_Y	lateral force, lb
M_X	moment about X-axis, ft-lb
M_Y	moment about Y-axis, ft-lb
M_Z	moment about Z-axis, ft-lb
q	free-stream dynamic pressure, lb/sq ft

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S	wing area including body intercept, sq ft
b	wing span, ft
A	aspect ratio
Λ_{LE}	sweep of leading edge, deg
λ	taper ratio
$\bar{c}$	wing mean geometric chord, ft
$\bar{c}_t$	horizontal-tail mean aerodynamic chord
$\bar{c}_v$	vertical-tail mean aerodynamic chord
M	Mach number
α	angle of attack, deg
β	angle of sideslip, deg
$\Delta C_D'$	incremental longitudinal-force coefficient
ΔC_n	incremental yawing-moment coefficient
ΔC_l	incremental rolling-moment coefficient
ΔC_Y	incremental lateral-force coefficient
C_{n_β}	static directional stability derivative
C_{l_β}	effective dihedral derivative

Model designations:

W	wing
B	body
H	horizontal tail
V_o	original vertical tail

MODEL

Geometric characteristics of the model are given in figure 2 and table I. The model was equipped with pylon-mounted stores located at 23.8, 46.2, and 67.0 percent of the wing semispan. The inboard and outboard stores were constructed to Douglas Aircraft Company, Inc., (DAC) coordinates and represented 1,000-pound and 500-pound bombs, respectively. The stores located at 46.2 percent of the wing semispan represented large fuel tanks and had an unsymmetrical shape and were equipped with fins. Figure 3 shows schematically some details of the store arrangements.

The model was sting-supported with a six-component strain-gage balance enclosed within the fuselage.

TESTS

The tests were conducted in the Langley 4- by 4-foot supersonic pressure tunnel at Mach numbers of 1.61 and 2.01 with a stagnation pressure maintained at 6 pounds per square inch absolute and a stagnation temperature at 100° F. The dewpoint was held at approximately -20° F.

The individual and combined effects of the tanks, outboard stores, and inboard stores on the longitudinal and lateral aerodynamic characteristics of the model were investigated. Tests were made to a maximum angle of attack and sideslip of approximately 20°. With increase in sideslip angle and/or Mach number, it was necessary to decrease the angle-of-attack range of the tests due to structural limitations of the apparatus. The Reynolds numbers corresponding to the Mach numbers of 1.61 and 2.01 were 1.34×10^6 and 1.16×10^6, respectively.

RESULTS

The results obtained with various store arrangements are presented in figures 4 to 13. It should be noted that the modified vertical tail used during tests at $M = 1.61$ had approximately 27 percent more area than the original tail used during tests at $M = 2.01$.

The angles of attack and sideslip have been corrected for deflections of the balance and sting under load. On the basis of pressure measurements made at the base of the fuselage, the longitudinal-force coefficients were adjusted to correspond to free-stream static pressure at the base.

Accuracy

The estimated errors in the various measured quantities are as follows:

	M = 1.61	M = 2.01
C_L	±0.0044	±0.0051
C_D'	±0.0005	±0.0007
C_m	±0.0017	±0.0021
C_n	±0.0003	±0.0003
C_Y	±0.0020	±0.0020
C_l	±0.0002	±0.0002

Also,

α, β, deg . . . . ±0.1

Mach number . . . . ±0.01

Remarks on Effects of Stores

The addition of various stores resulted mainly in an increase in drag. The addition of either the inboard or outboard DAC stores resulted in an incremental drag coefficient $\Delta C_D'$ near $C_L = 0$ at $M = 1.61$ of approximately 0.0040 (fig. 10). This is of particular interest when it is considered that the inboard DAC stores were approximately 25 percent larger than the outboard DAC stores. The tanks, which were appreciably larger than either of the DAC stores, resulted in an incremental drag of 0.0100. The addition of all stores resulted in an increase in drag coefficient of the model at zero lift coefficient from 0.038 to 0.057 which amounts to an increase of approximately 10 percent more than the sum of the incremental drag coefficients obtained with these stores attached individually to the model.

All stores with the exception of the outboard DAC store caused small positive trim changes.

The results obtained for $M = 2.01$ (fig. 5) with and without the horizontal tail on indicate that a small decrease in longitudinal stability due to the addition of stores occurred only for the configurations with the horizontal tail on; hence, it would appear that the decrease in longitudinal stability is the result of an interference effect of the stores on the horizontal tail.

The data presented in figures 6 and 7 indicate that, within the limits of the investigation, all store configurations with the exception of the outboard DAC stores alone caused an increase in positive effective dihedral. The results obtained with various individual stores (figs. 6 and 11) indicate that the addition of the inboard DAC stores resulted in a decrease in C_{n_β} at $\alpha = 0^\circ$ ($M = 1.61$) becoming zero at $\alpha = 15^\circ$; whereas, the addition of the tanks resulted in an increase in C_{n_β} for angles of attack greater than approximately 12°. The effects of combinations of stores on C_{n_β} as compared with the effects of various individual stores were somewhat more unfavorable at low and moderate angles of attack. A comparison of figures 6 and 7 indicates that the effects of inboard DAC stores in combination with the tanks on the C_{n_β} and C_{l_β} were essentially the same at $M = 2.01$ as at $M = 1.61$. On the basis of results presented in figure 8 for $M = 2.01$, it appears that adverse effect of inboard stores or combinations of stores including the inboard stores arises from interference effects of the stores on the vertical tail.

Langley Aeronautical Laboratory,
National Advisory Committee for Aeronautics,
Langley Field, Va., May 25, 1956.

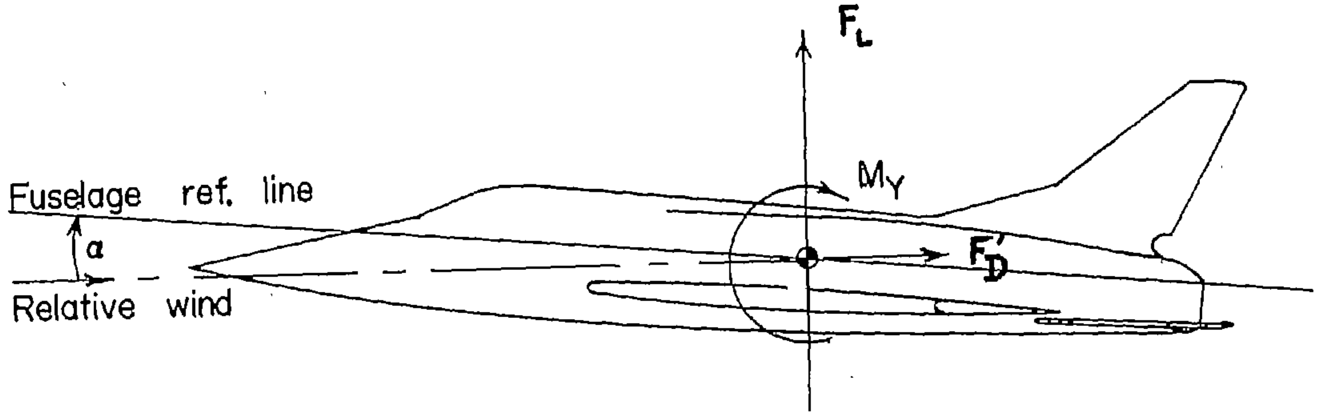
REFERENCES

1. Driver, Cornelius, and Foster, Gerald V.: Static Longitudinal Stability and Control Characteristics of a Model of a 45° Swept-Wing Fighter Airplane at Mach Numbers of 1.41, 1.61, and 2.01. NACA RM L56D04, 1956.

2. Spearman, M. Leroy, and Robinson, Ross B.: Static Lateral Stability and Control Characteristics of a Model of a 45° Swept-Wing Fighter Airplane With Various Vertical Tails at Mach Numbers of 1.41, 1.61, and 2.01. NACA RM L56D05, 1956.

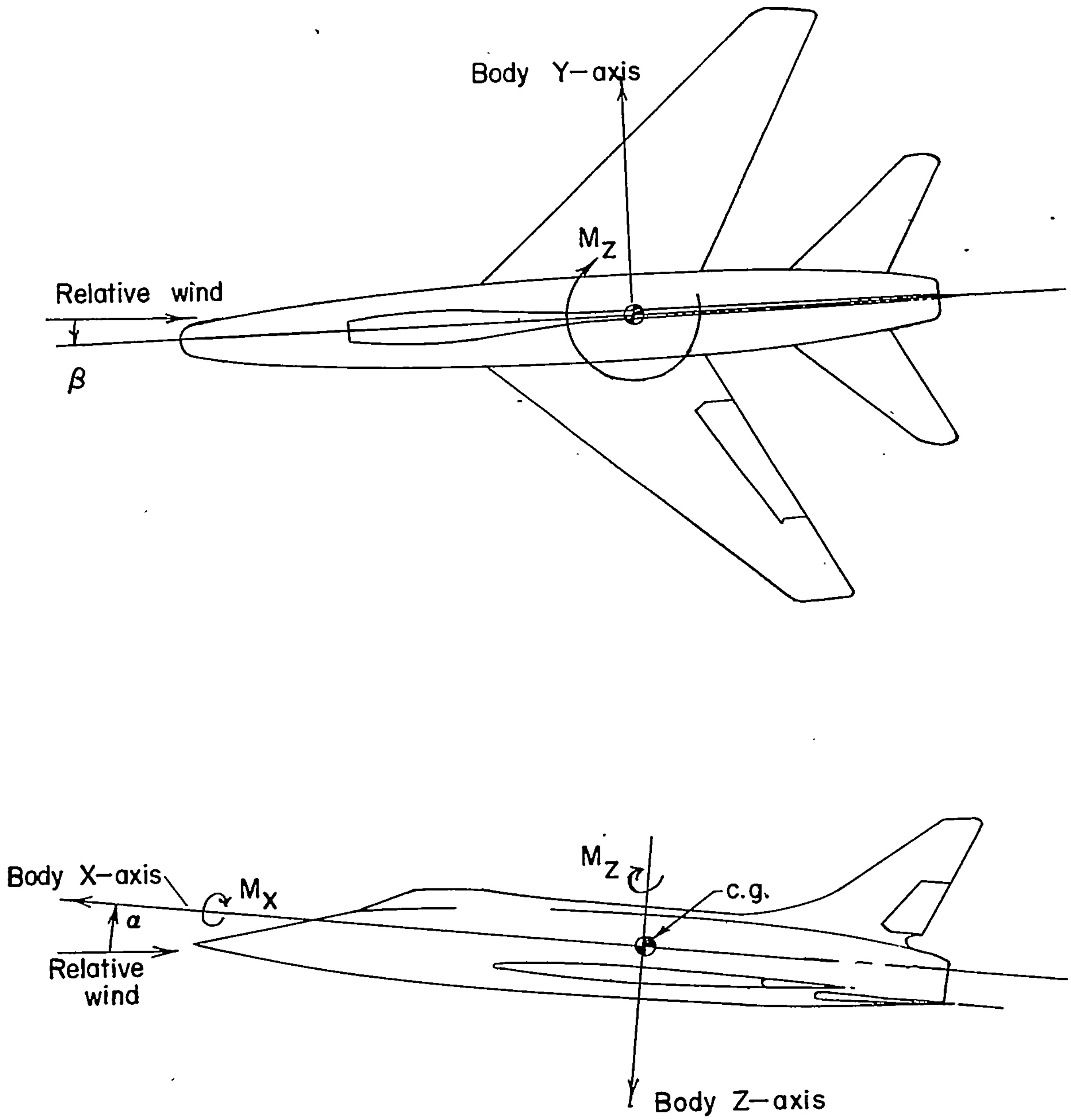
TABLE I.- GEOMETRIC CHARACTERISTICS OF THE MODEL

Wing:	
Area, sq ft	1.89
Span, in.	32.41
Aspect ratio	3.86
Taper ratio	0.262
Mean geometric chord, in.	9.38
Sweep of quarter-chord line, deg	45
Incidence, deg	0
Dihedral, deg	0
Twist, deg	0
Airfoil section	NACA $64_{(06)}$A007
Horizontal tail:	
Area, sq ft	0.48
Span, in.	15.73
Aspect ratio	3.54
Taper ratio	0.302
Mean geometric chord, in.	4.88
Sweep of quarter-chord line, deg	45
Airfoil section	NACA 65A003.5
Tail length, $0.25\bar{c}$ of wing to $0.25\bar{c}$ of horizontal tail, in.	12.07
Original vertical tail:	
Area, sq ft	0.164
Span (exposed), in.	5.16
Aspect ratio	1.10
Taper ratio	0.428
Mean geometric chord, in.	4.90
Sweep of quarter-chord line, deg	45
Airfoil section	NACA 65A003.5
Tail length, $0.25\bar{c}$ of wing to $0.25\bar{c}$ of vertical tail, in.	13.36
Modified vertical tail:	
Area, sq ft	0.213
Span	6.66
Aspect ratio	1.45
Mean geometric chord, in.	5.61
Sweep of quarter-chord line, deg	45
Airfoil section	NACA 65A003.5
Tail length, $0.25\bar{c}$ of wing to $0.25\bar{c}$ of vertical tail, in.	14.42
Fuselage:	
Length, in.	40.45
Frontal area, sq ft	0.13



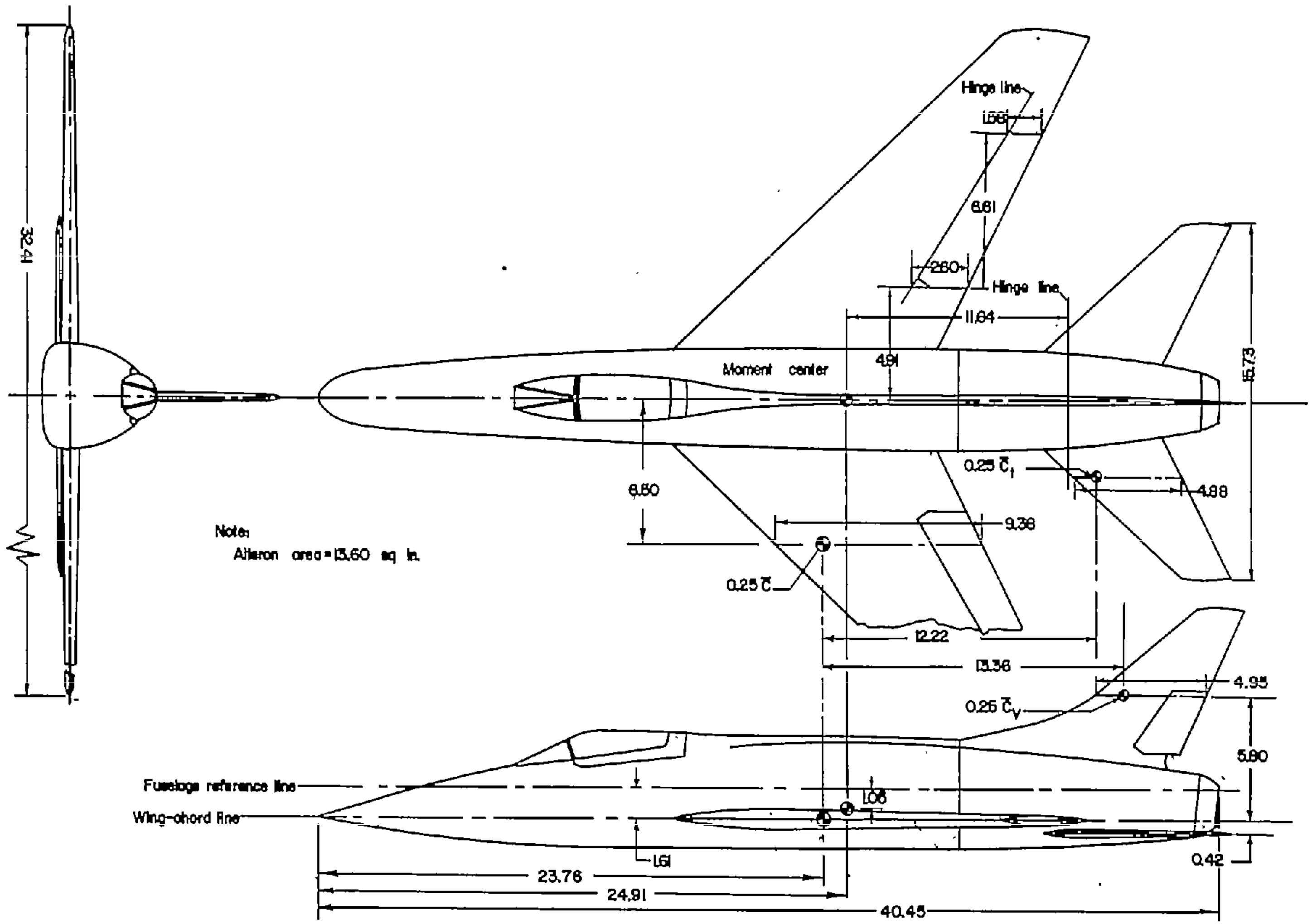
(a) Stability-axis system.

Figure 1.- Axis systems. Arrows indicate positive directions.



(b) Body-axis system.

Figure 1.- Concluded.



(a) Three-view drawing of model.

Figure 2.- Details of model. All dimensions in inches.

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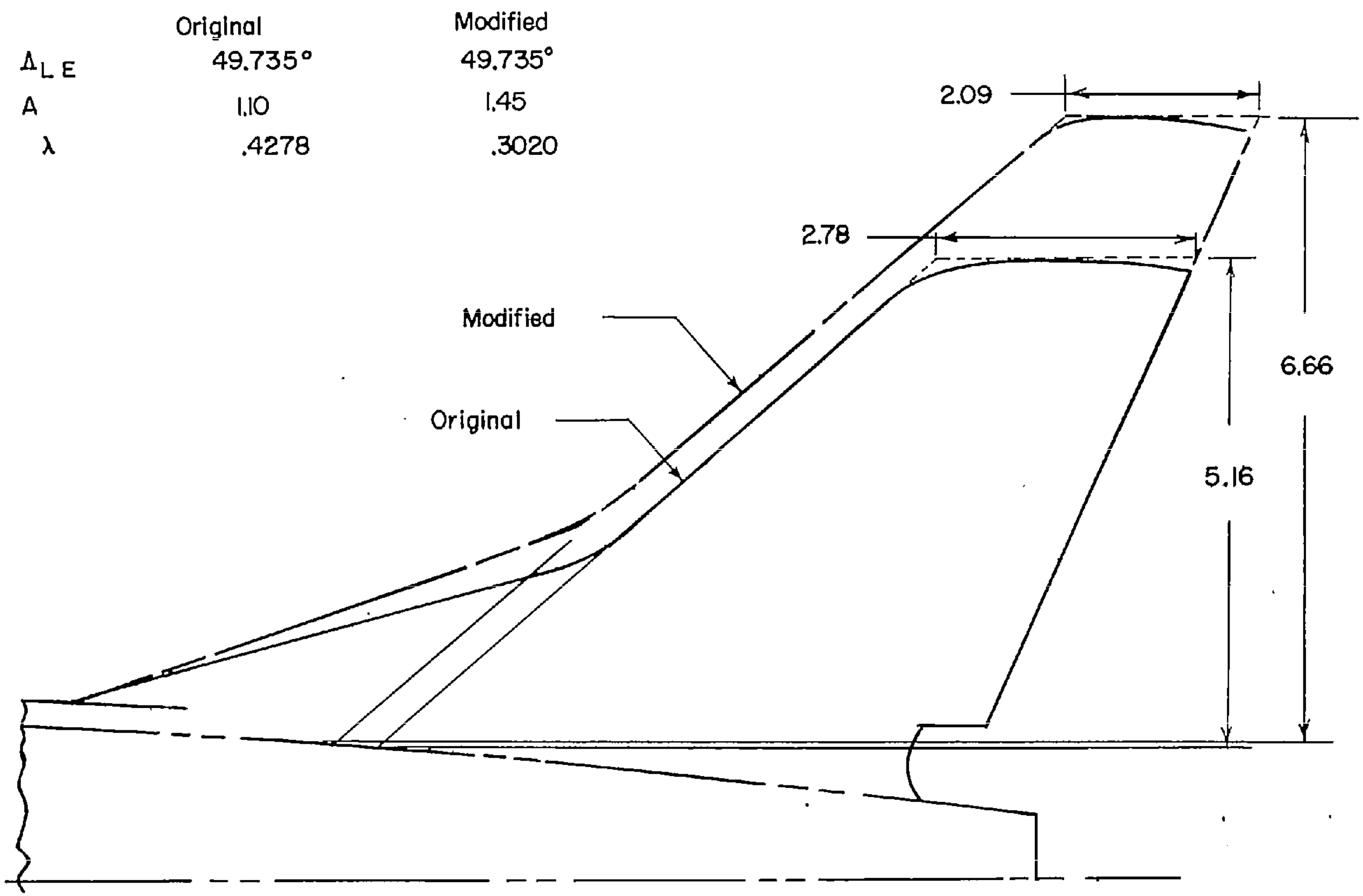

(b) Plan view of original and modified vertical tail.

Figure 2.- Concluded.

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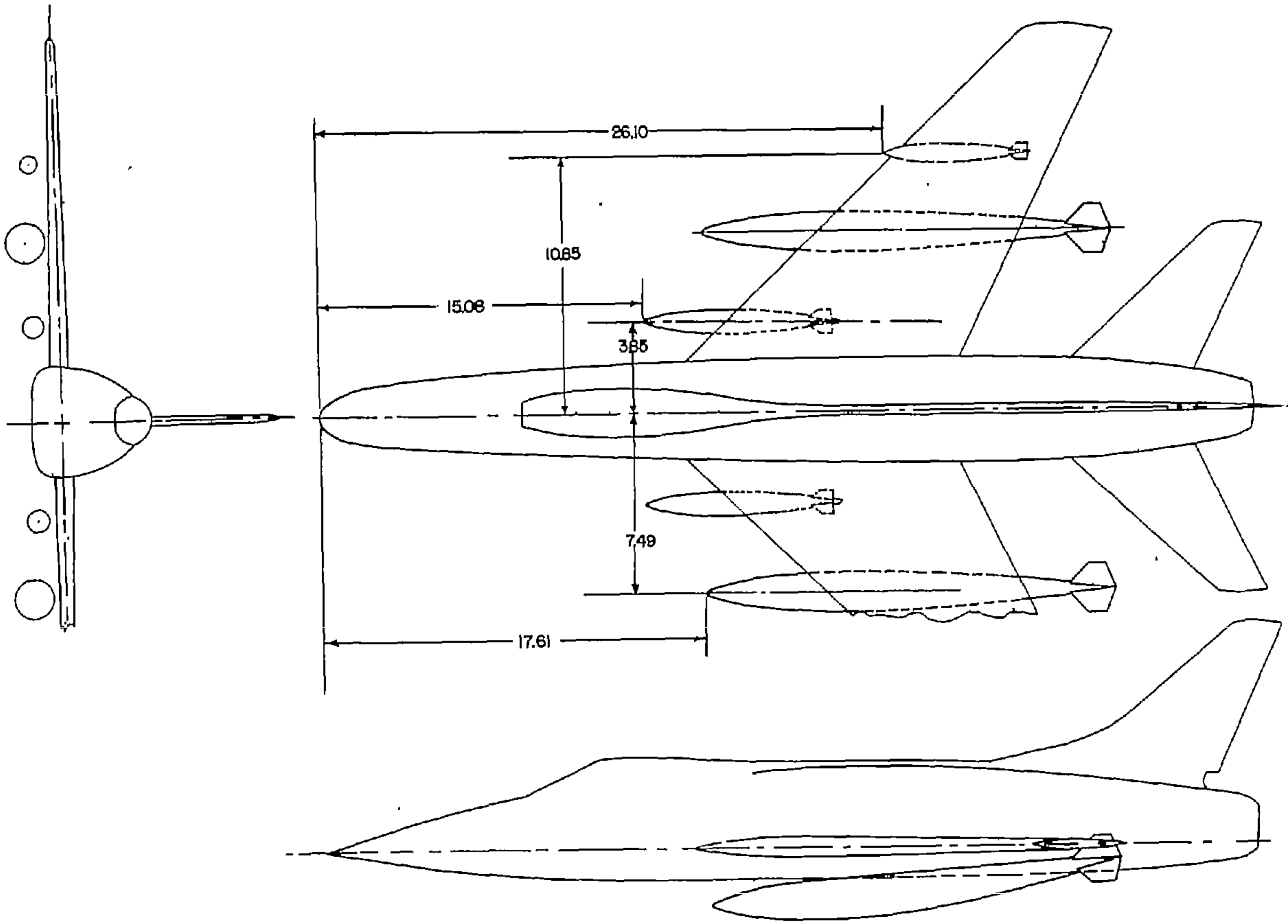

Figure 3.- Sketches showing position and relative size of external stores. All dimensions in inches.

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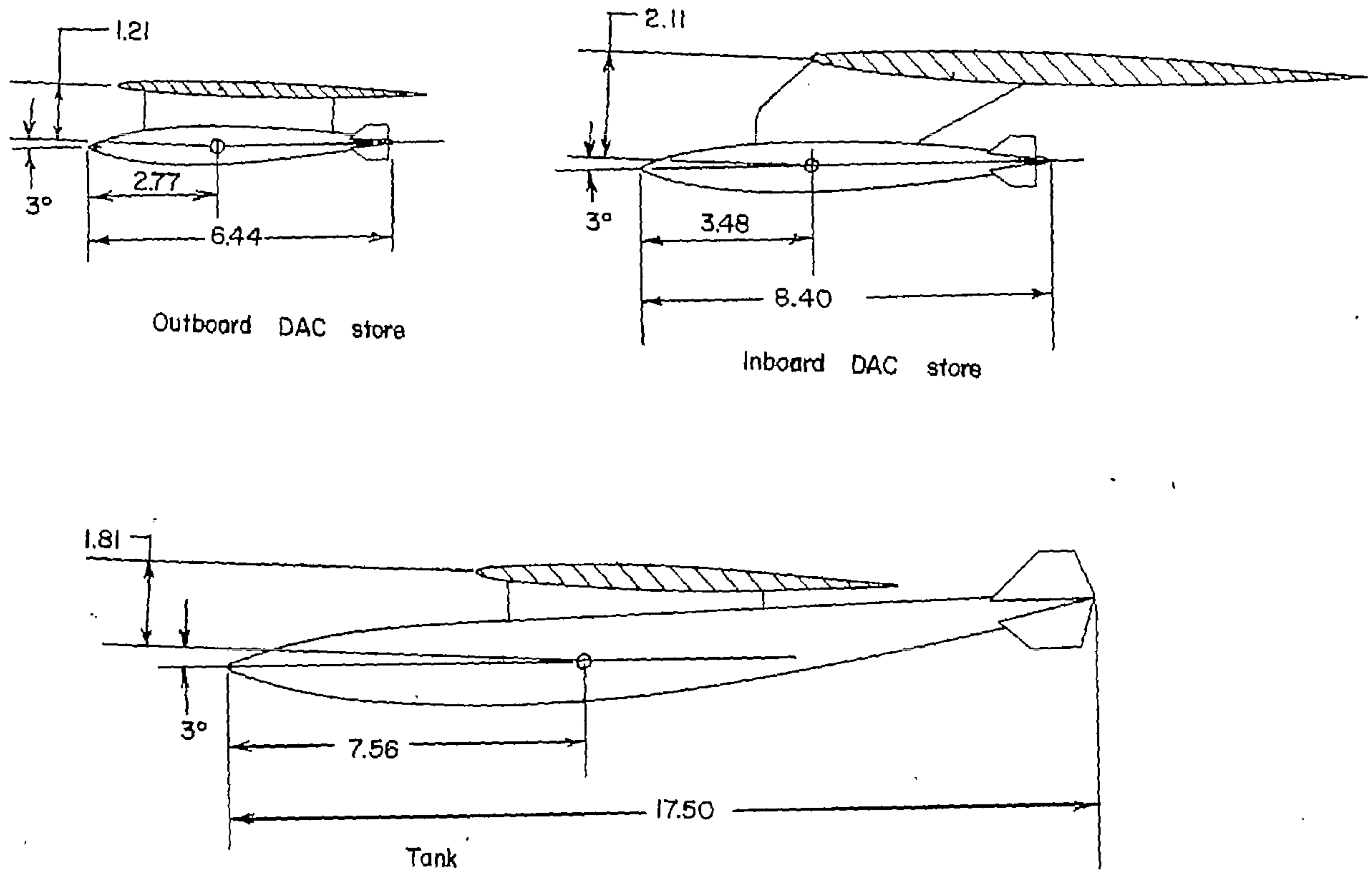


Figure 3.- Concluded.

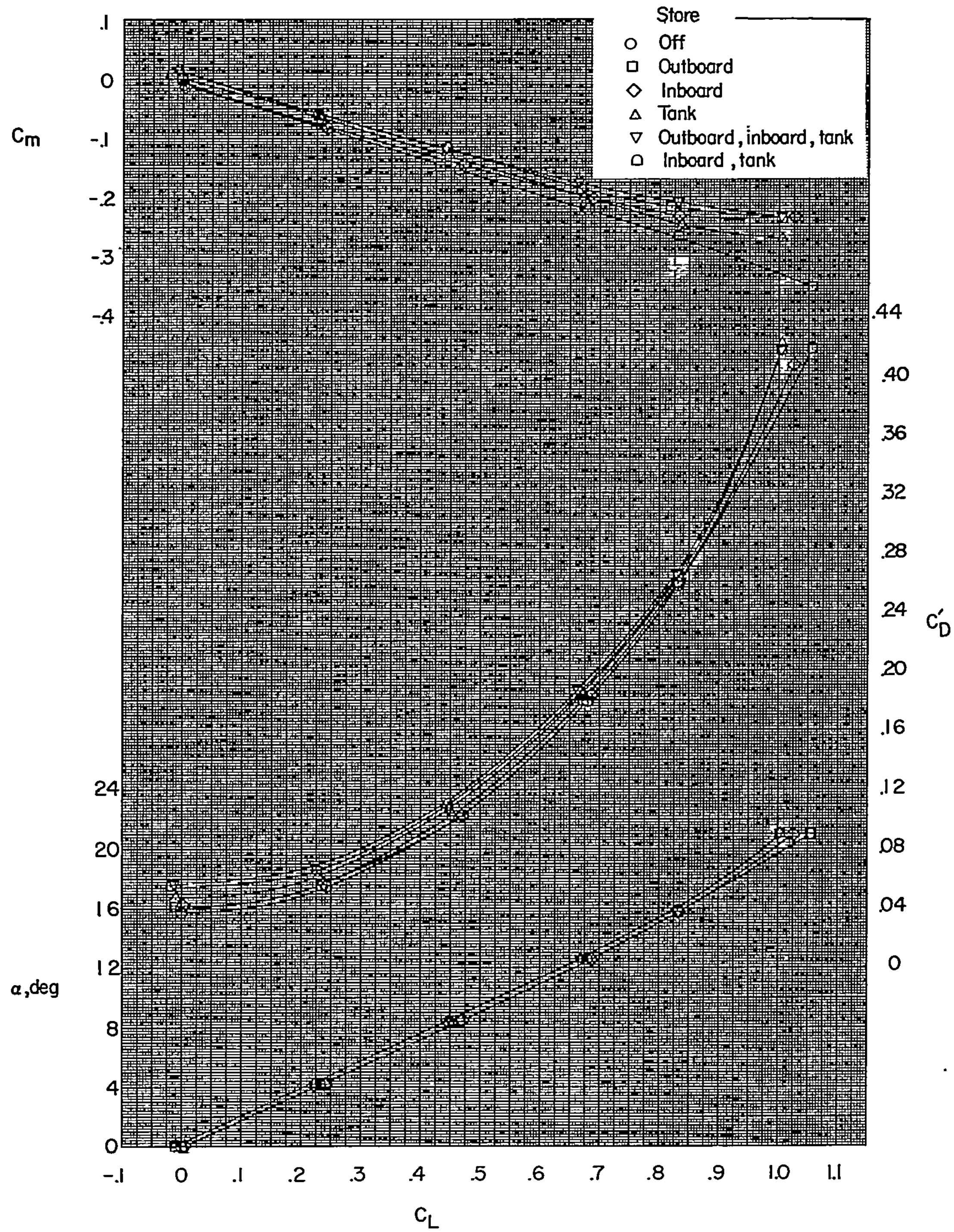


Figure 4.- Effects of various store arrangements on the longitudinal aerodynamic characteristics. Modified vertical tail; $\beta = 0^{\circ}$; $M = 1.61$.

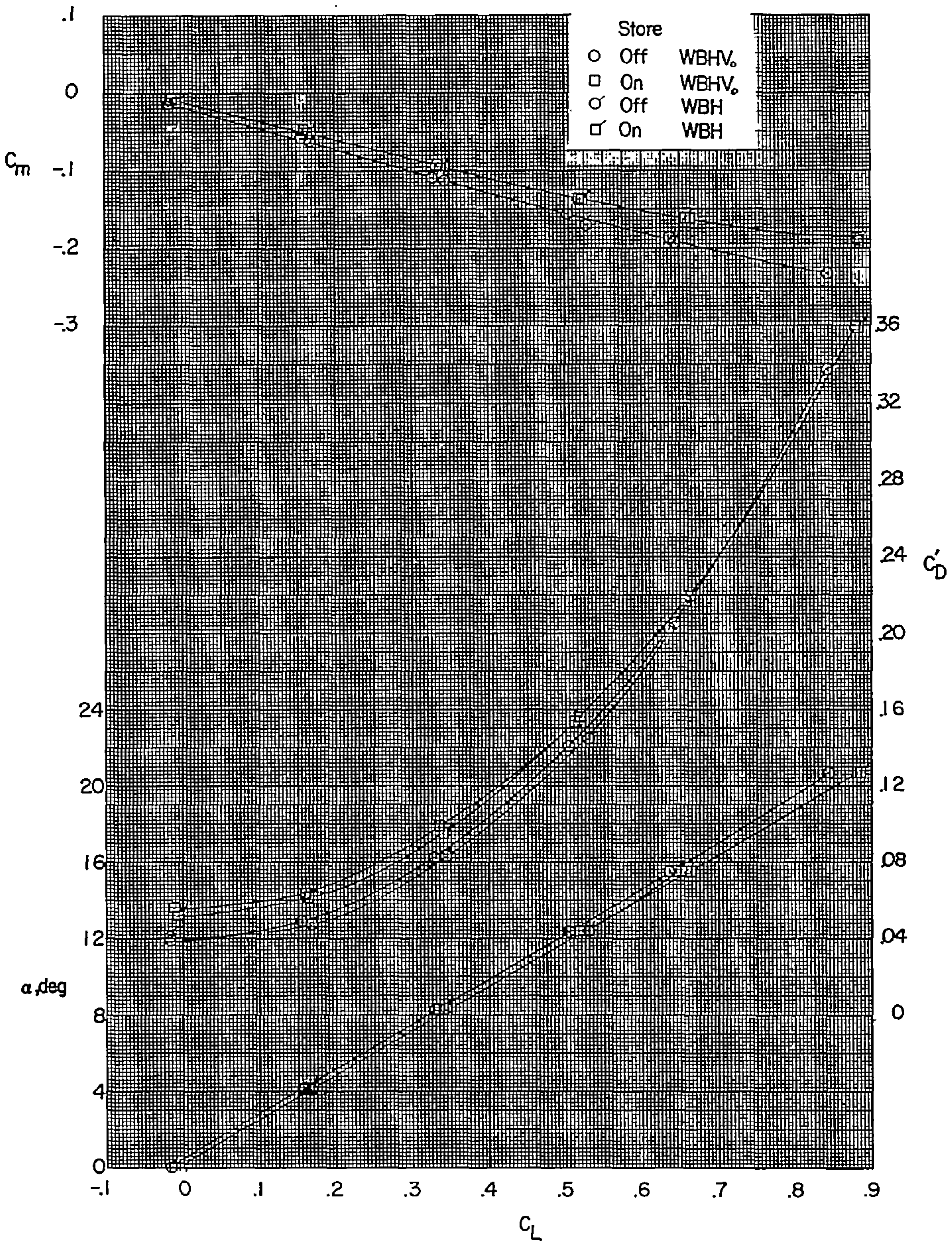


Figure 5.- Effect of inboard stores and tanks in combination on the longitudinal aerodynamic characteristics of the model with and without the original vertical tail. $\beta = 0^{\circ}$; $M = 2.01$.

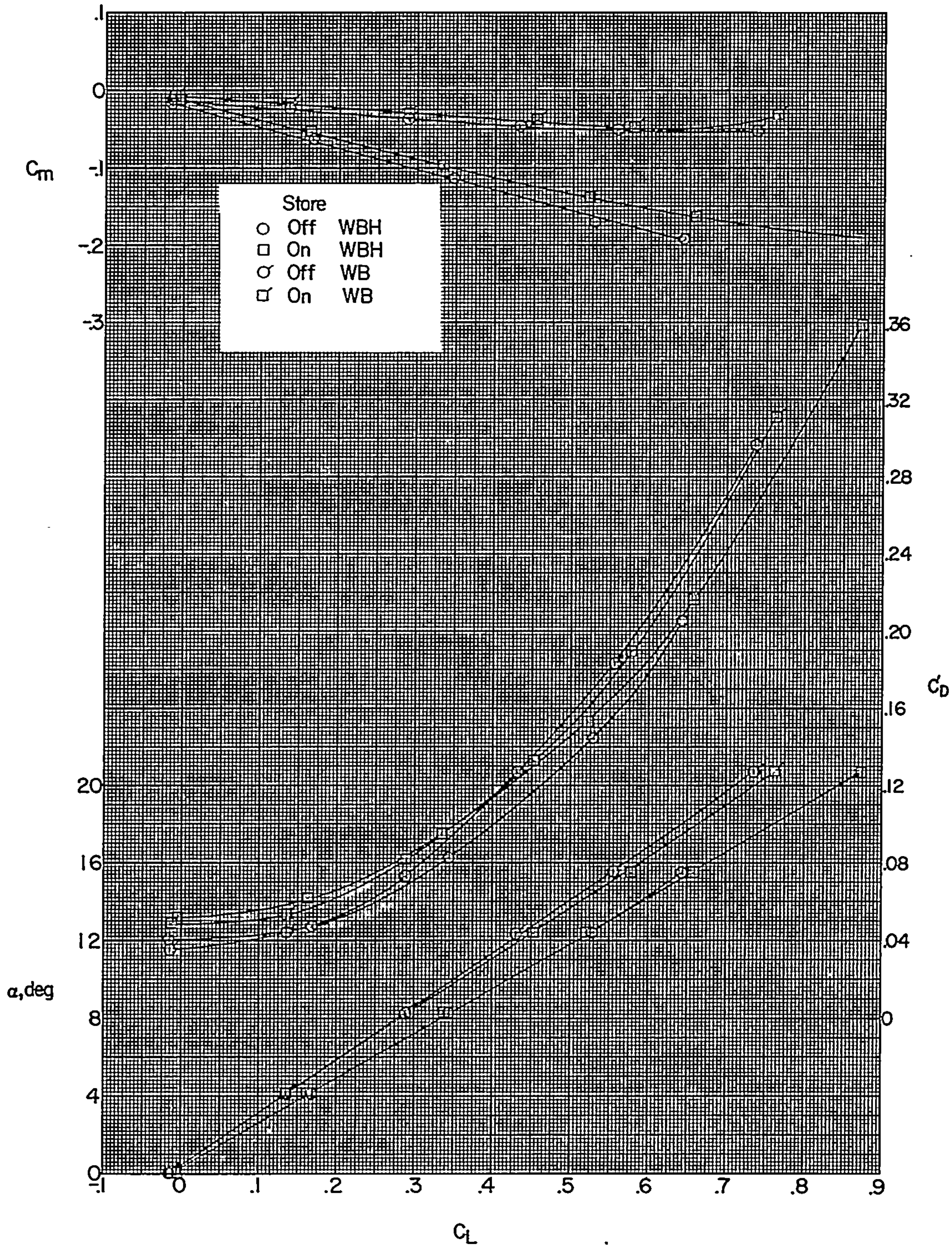


Figure 5.- Continued.

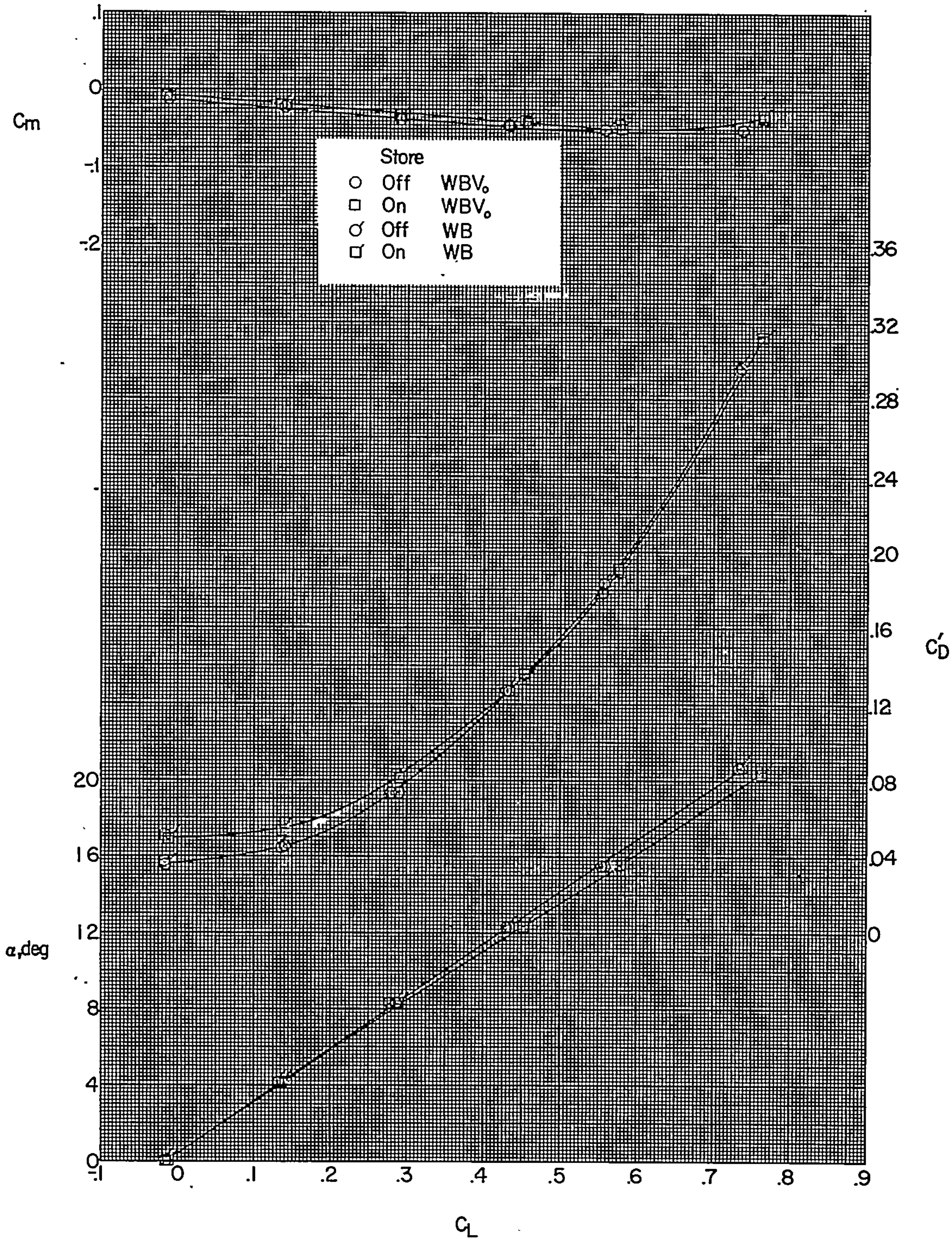
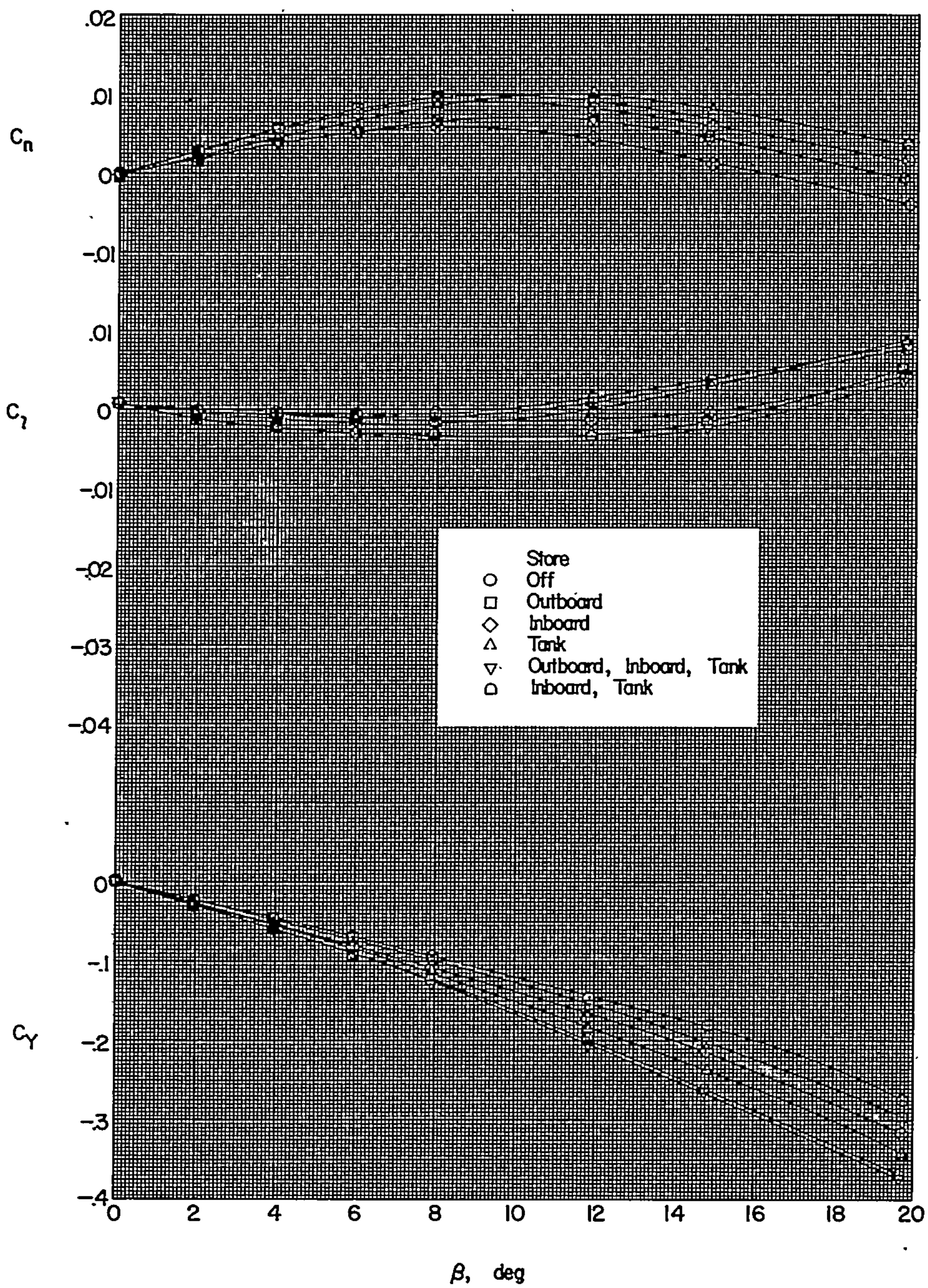
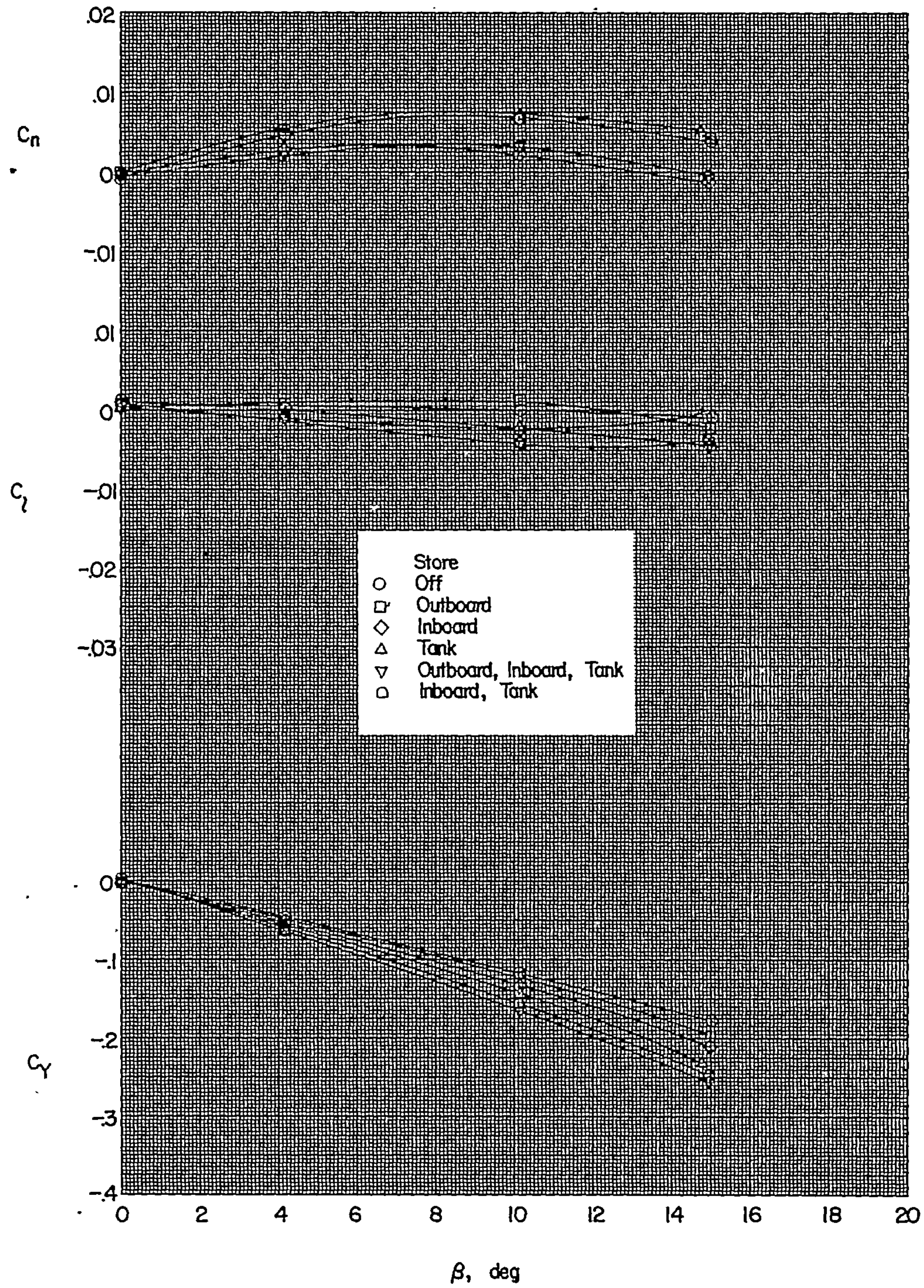


Figure 5.- Concluded.



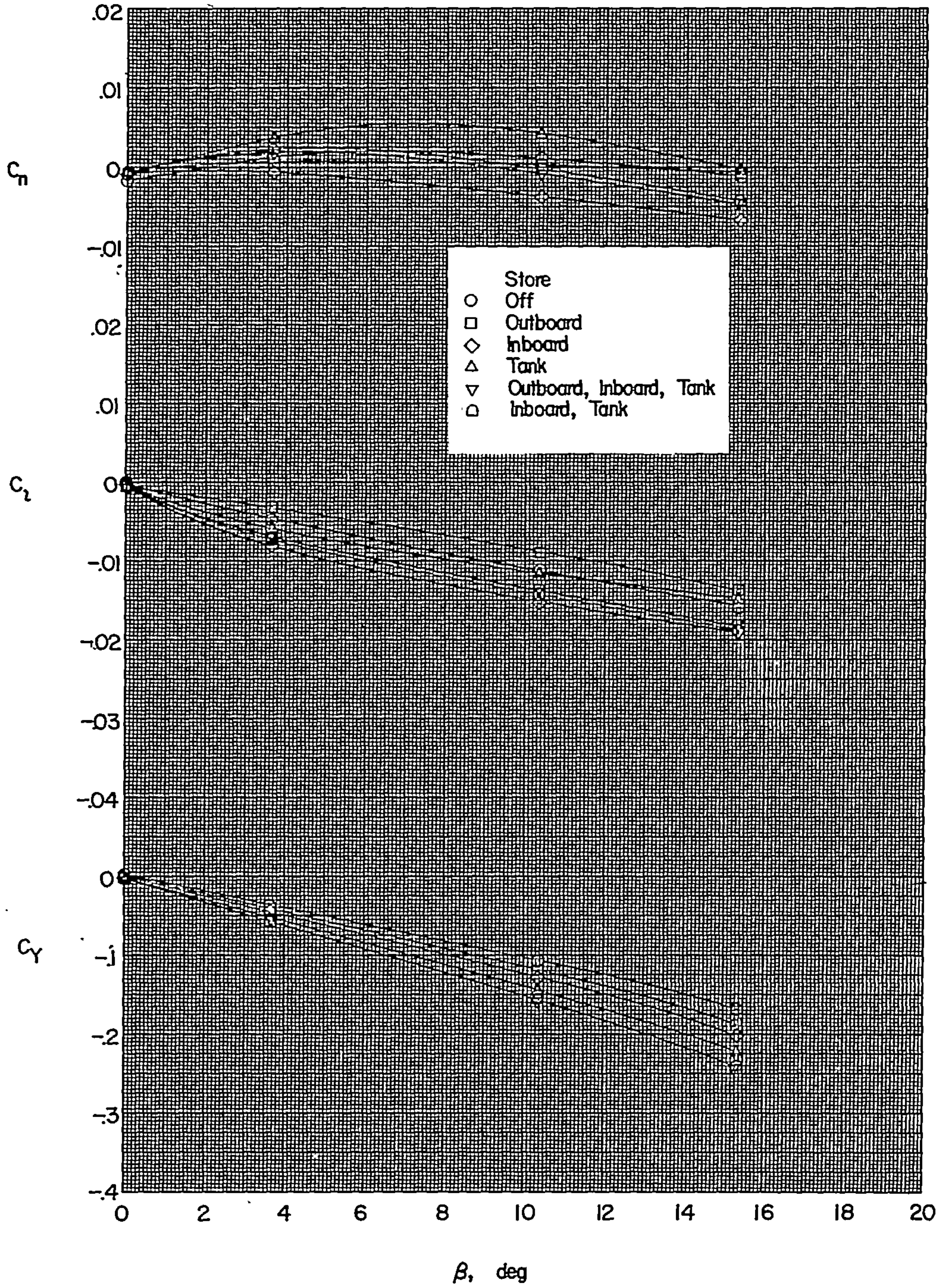
(a) $\alpha = 0^{\circ}$.

Figure 6.- Effect of various arrangements of stores on the lateral aerodynamic characteristics for various angles of attack. Modified vertical tail; M = 1.61.



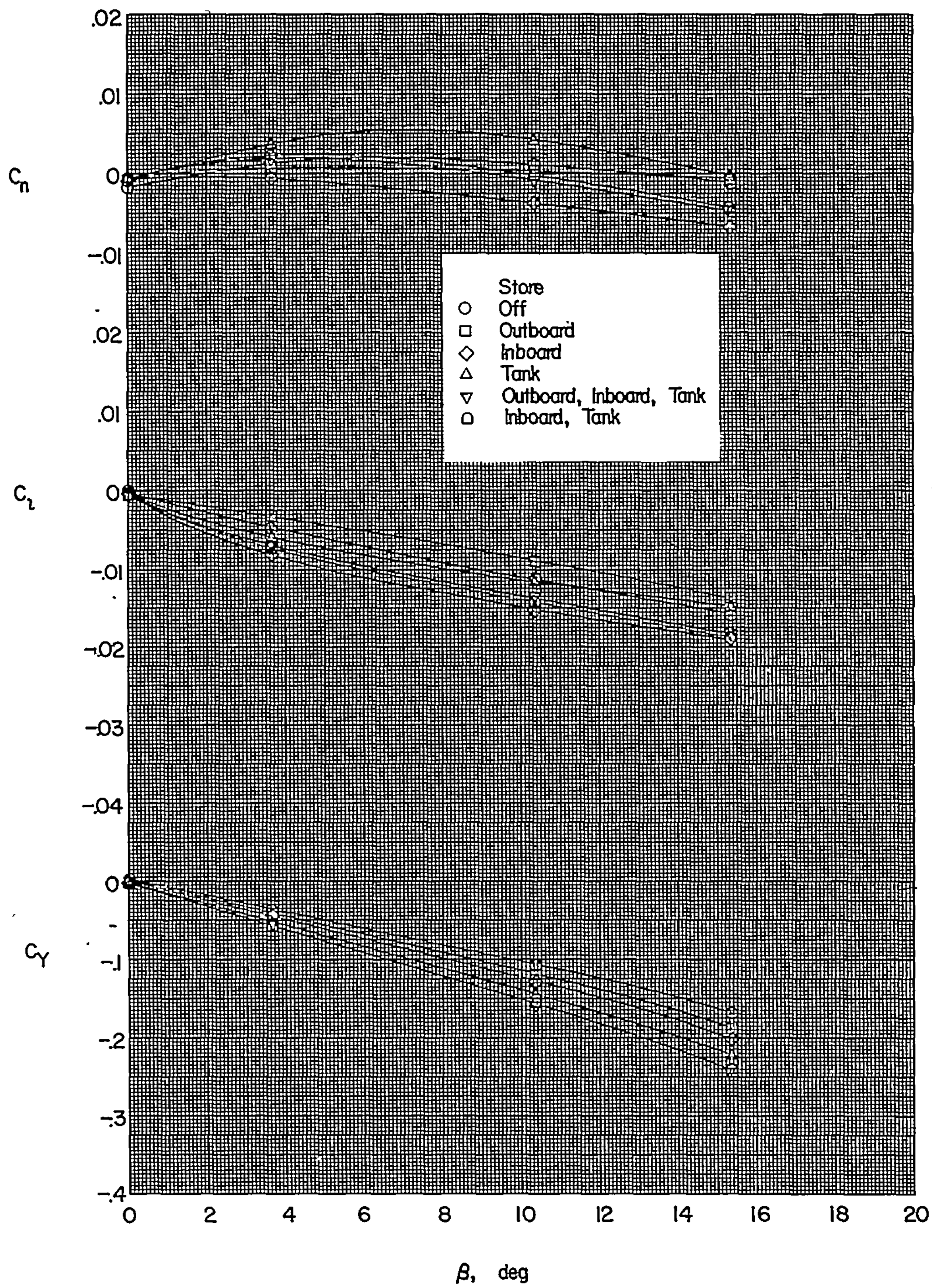
(b) $\alpha = 8^{\circ}$.

Figure 6.- Continued.



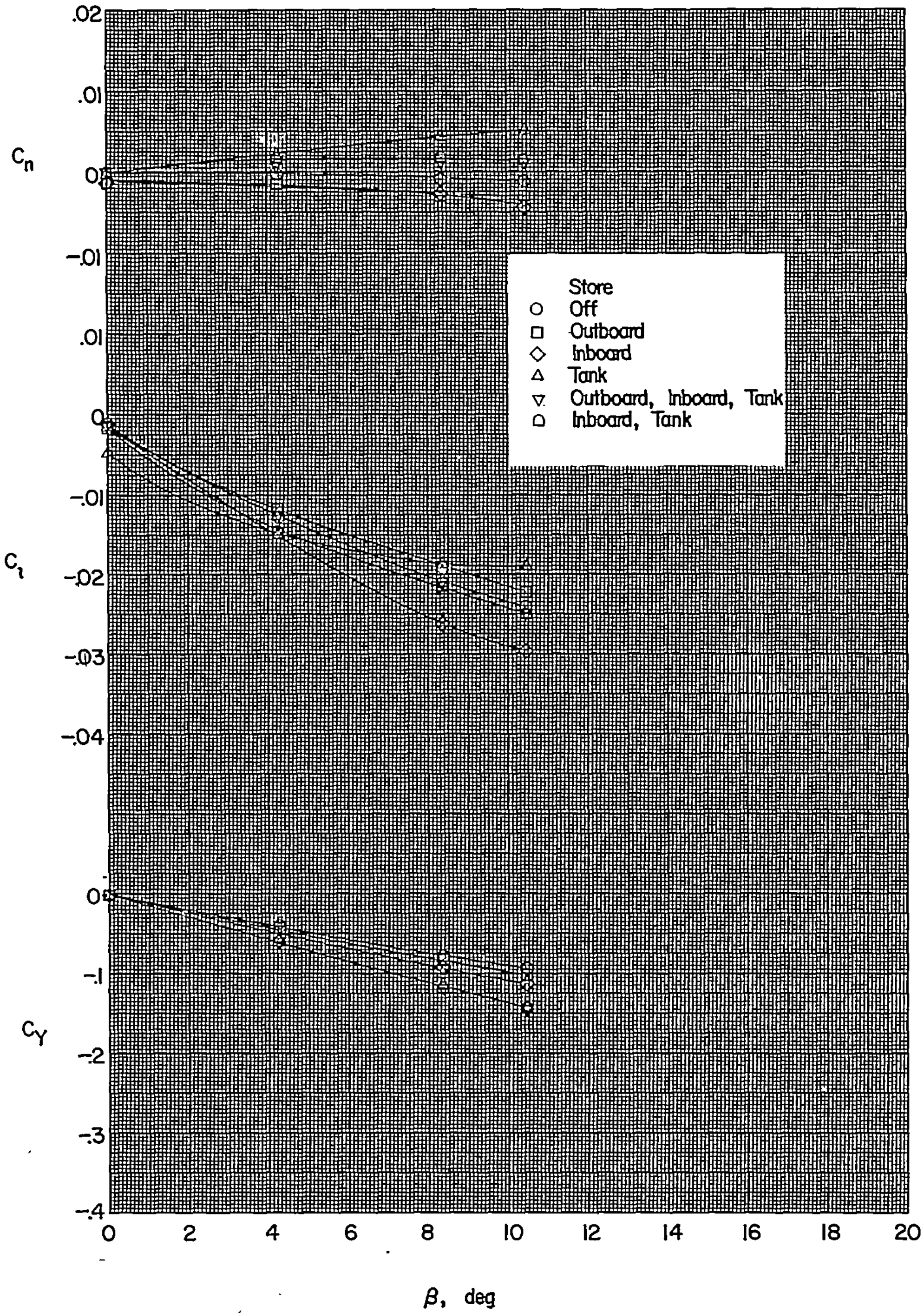
(c) $\alpha = 15^{\circ}$.

Figure 6.- Continued.



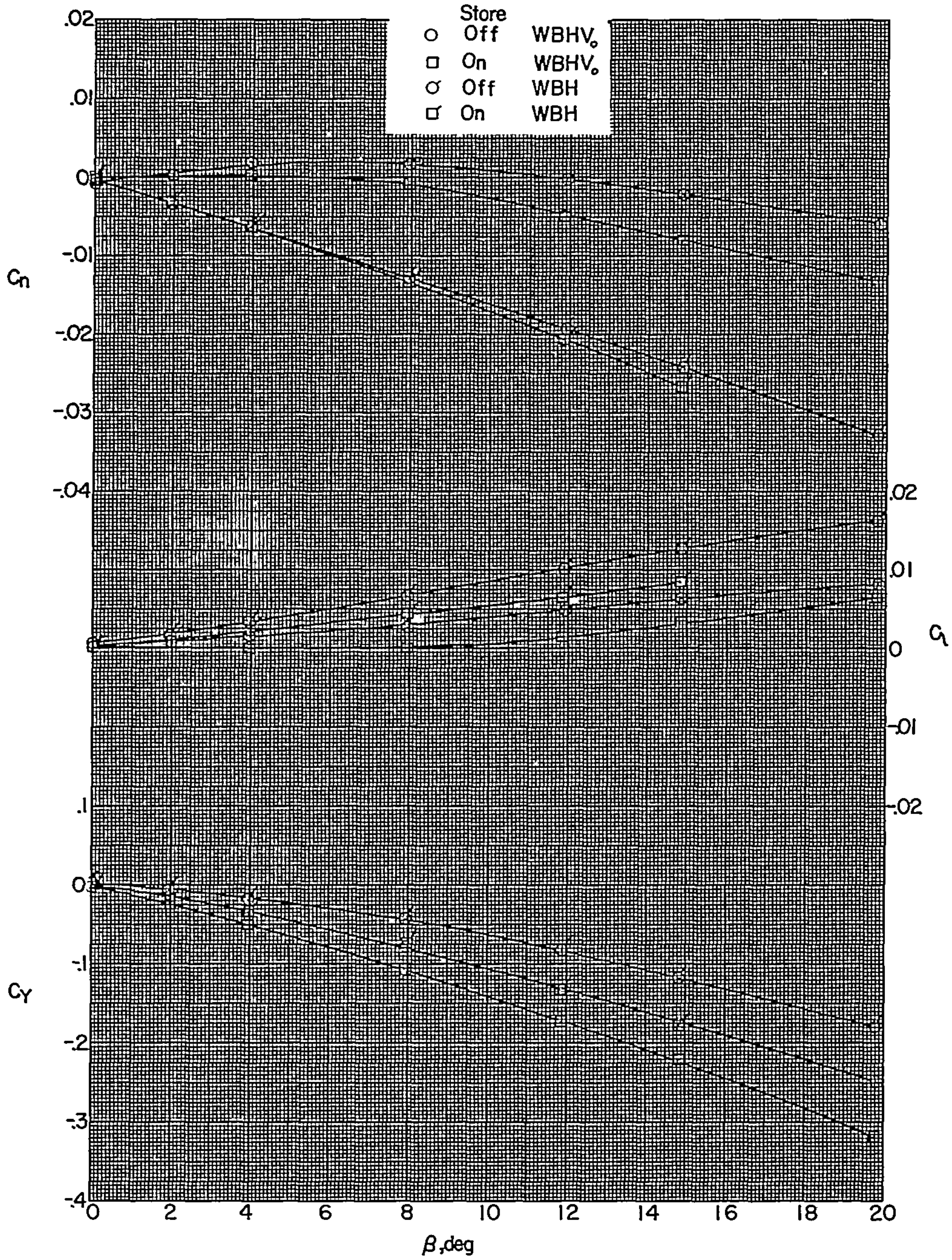
(c) $\alpha = 15^{\circ}$.

Figure 6.- Continued.



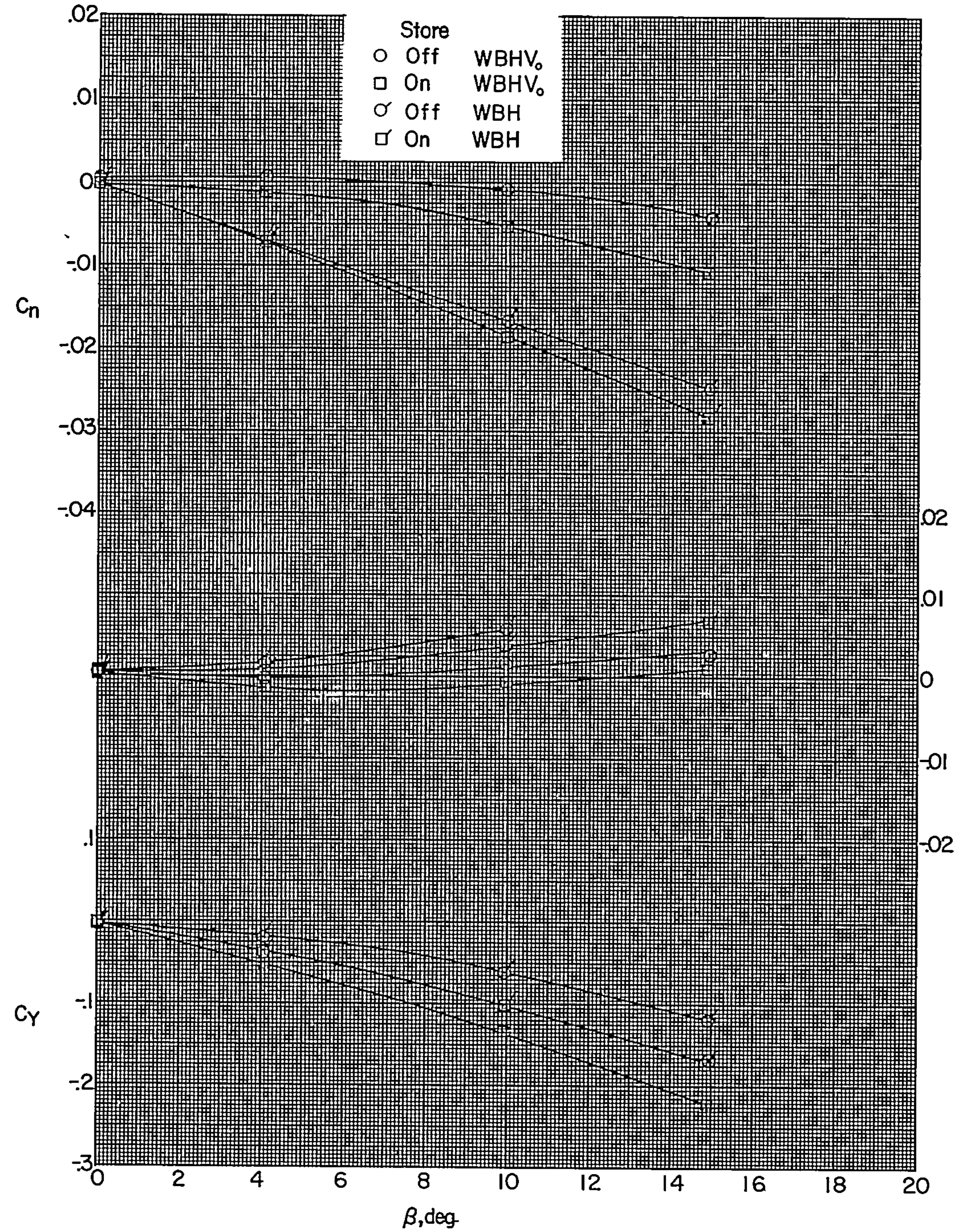
(d) $\alpha = 20^{\circ}$.

Figure 6.- Concluded.



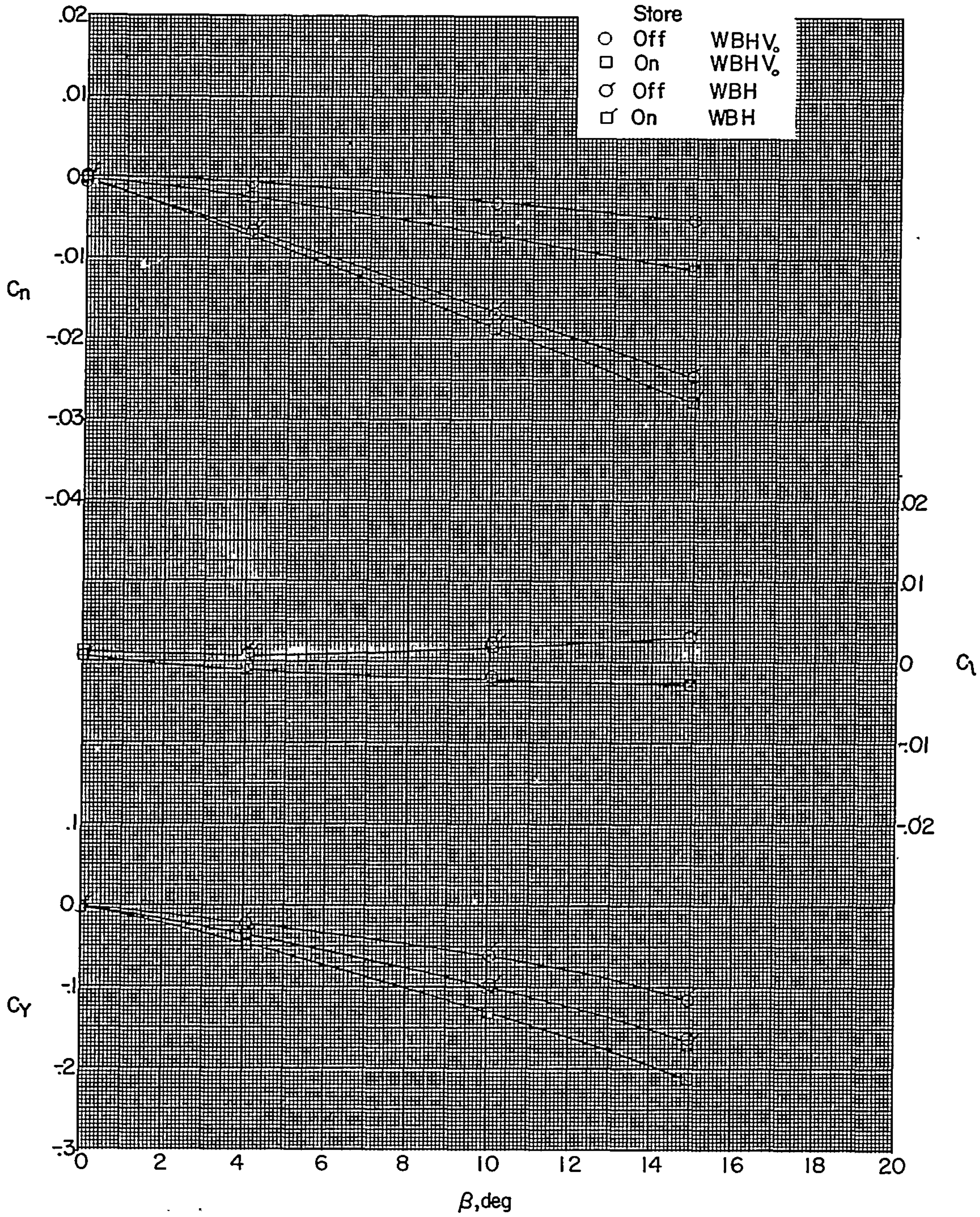
(a) $\alpha = 0^{\circ}$.

Figure 7.- Effect of inboard stores and tanks in combination on the lateral aerodynamic characteristics of the model with and without the original vertical tail for various angles of attack. M = 2.01.



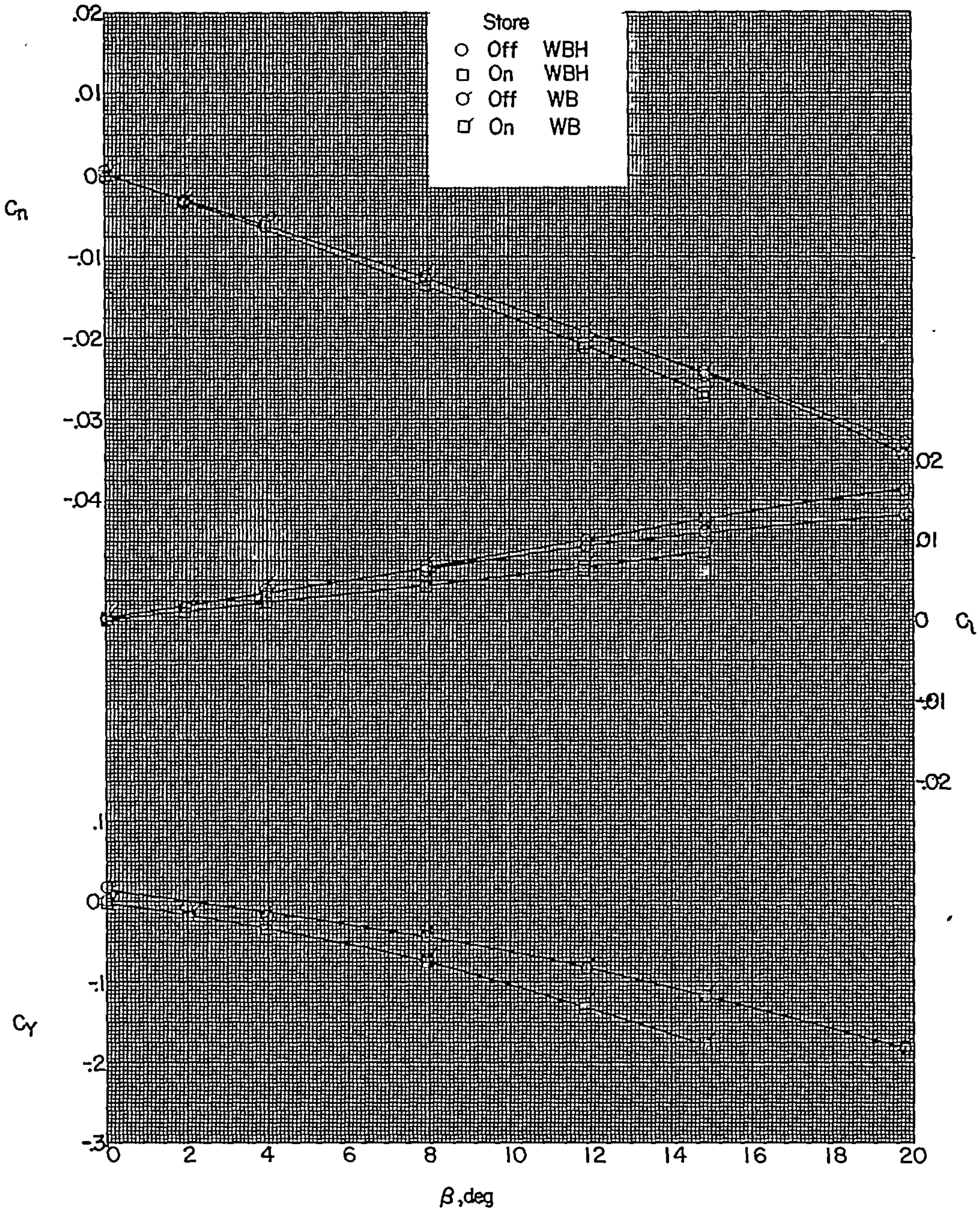
(b) $\alpha = 4^{\circ}$.

Figure 7.- Continued.



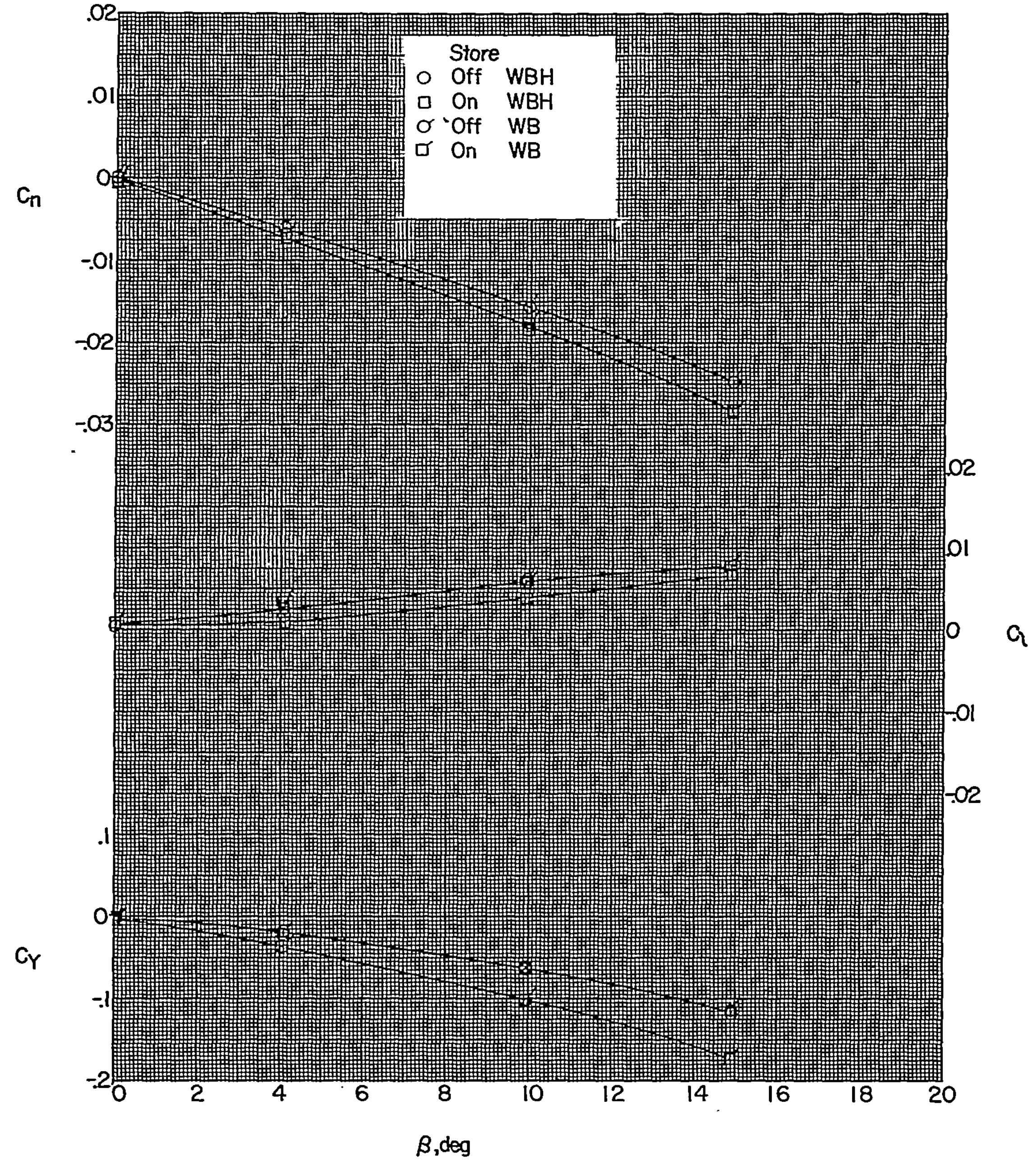
(c) $\alpha = 8^{\circ}$.

Figure 7.- Concluded.



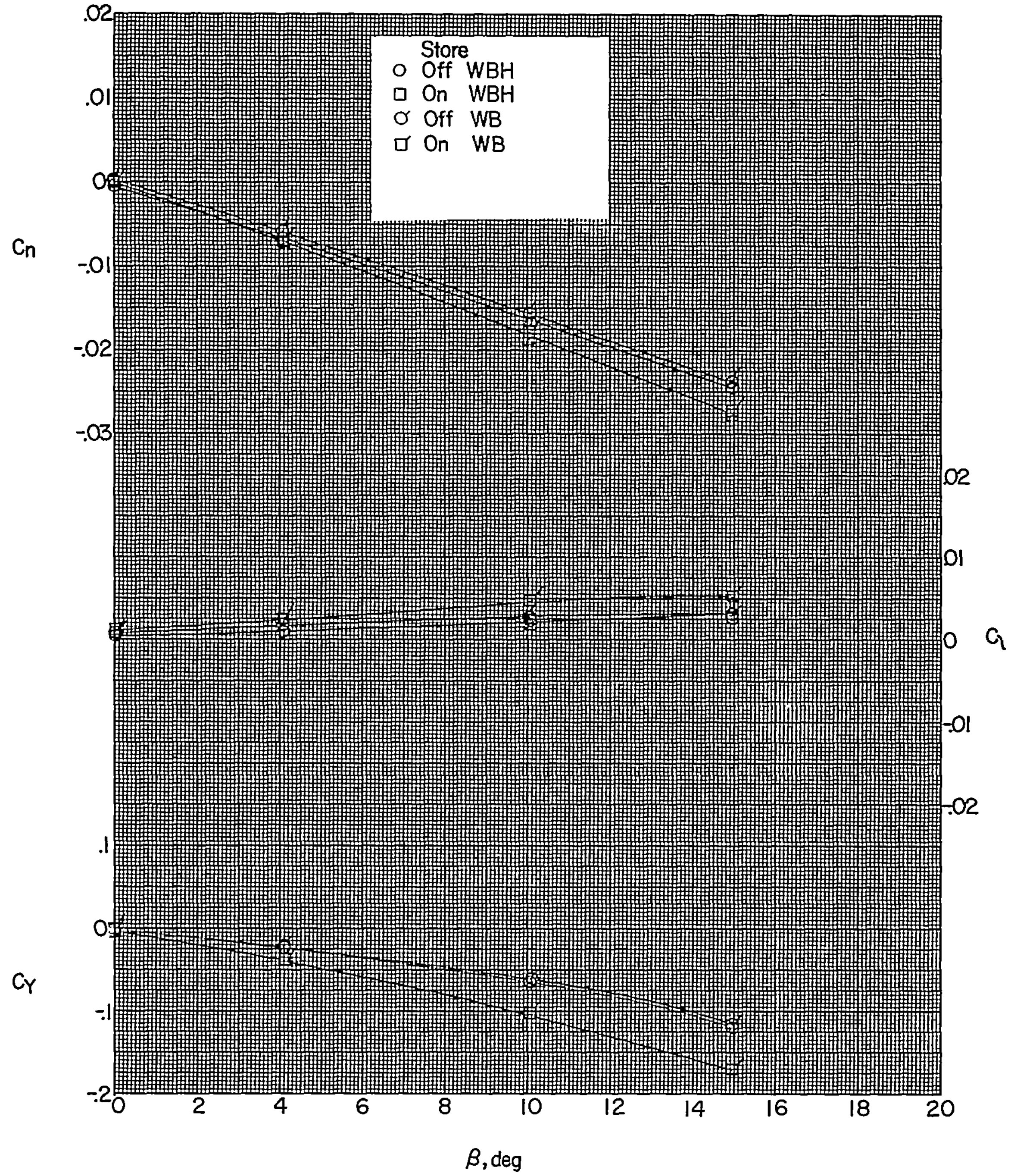
(a) $\alpha = 0^{\circ}$.

Figure 8.- Effect of inboard stores and tanks in combination on the lateral aerodynamic characteristics of the wing-fuselage configuration with and without horizontal tail for various angles of attack. $M = 2.01$.



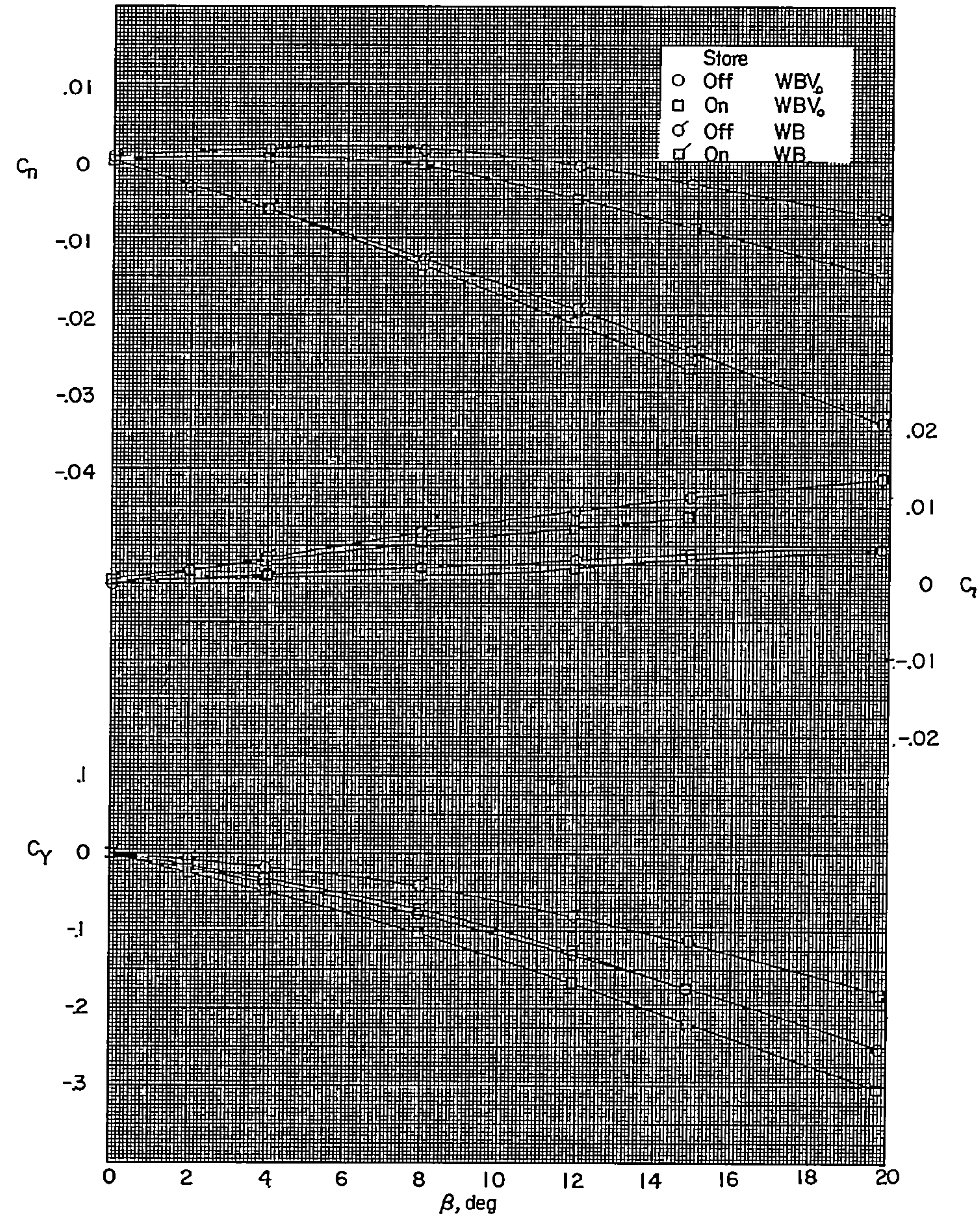
(b) $\alpha = 4^{\circ}$.

Figure 8.- Continued.



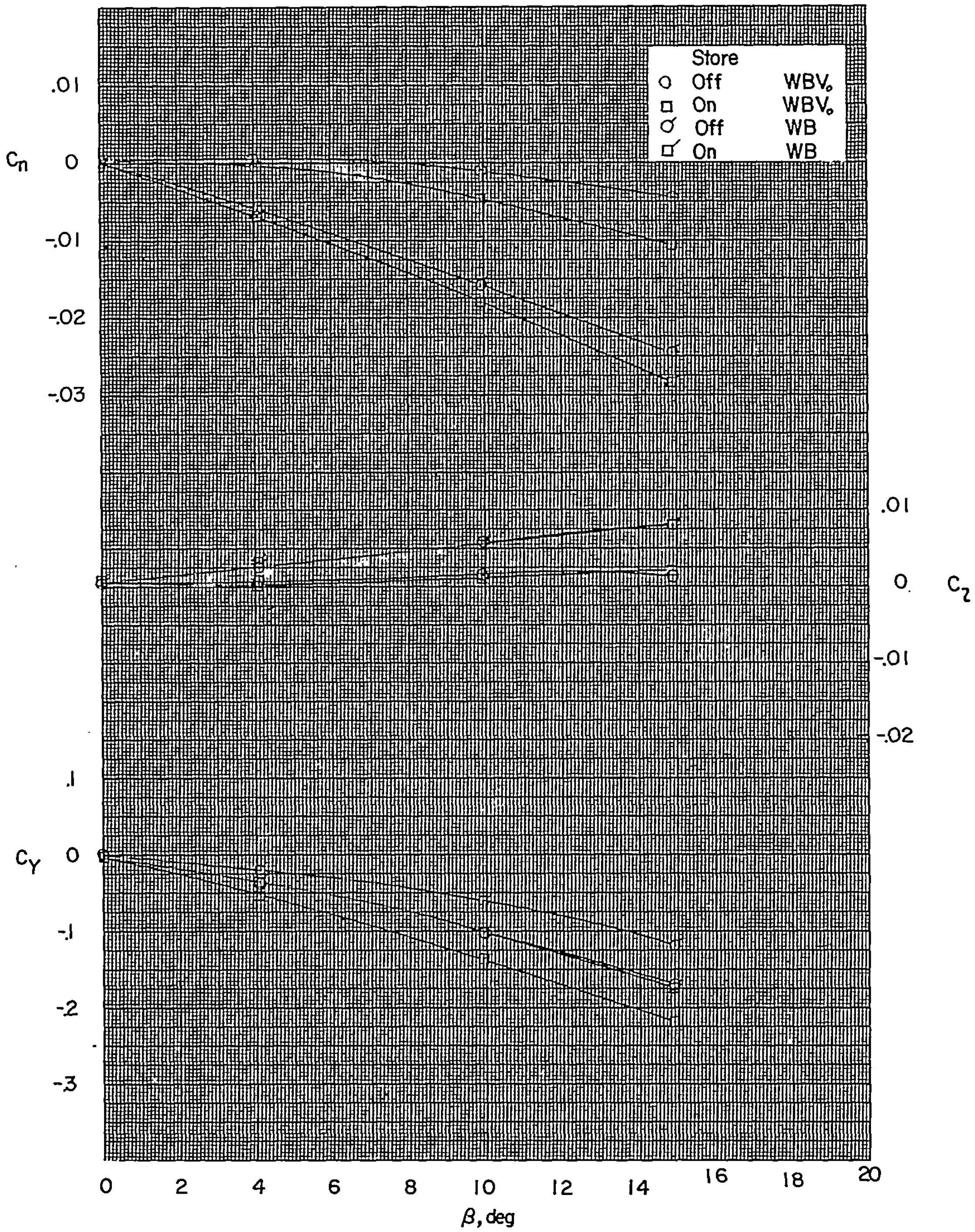
(c) $\alpha = 8^{\circ}$.

Figure 8.- Concluded.



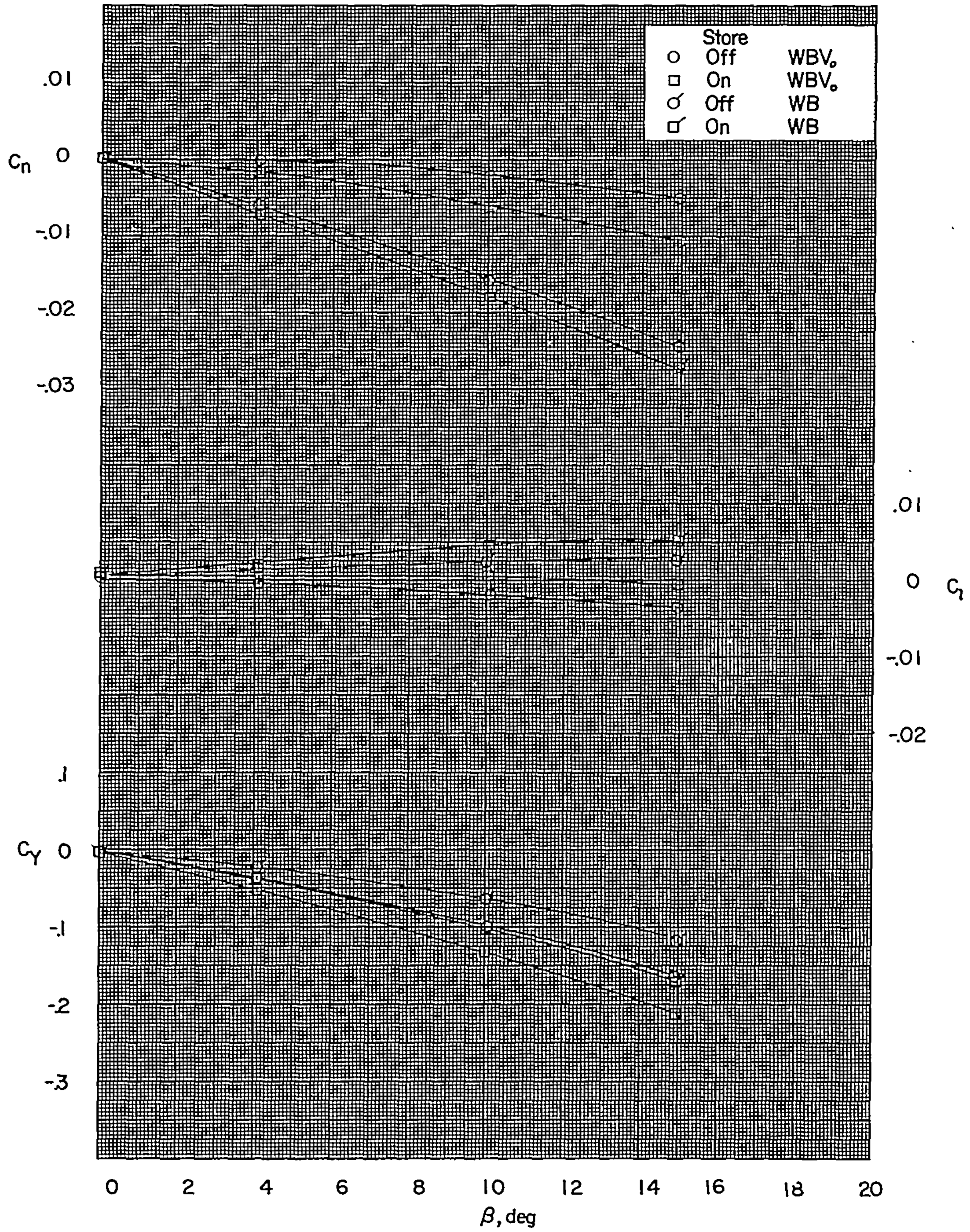
(a) $\alpha = 0^{\circ}$.

Figure 9.- Effect of inboard stores and tanks in combination on the lateral aerodynamic characteristics of the wing-fuselage configuration with and without the original vertical tail for various angles of attack. M = 2.01.



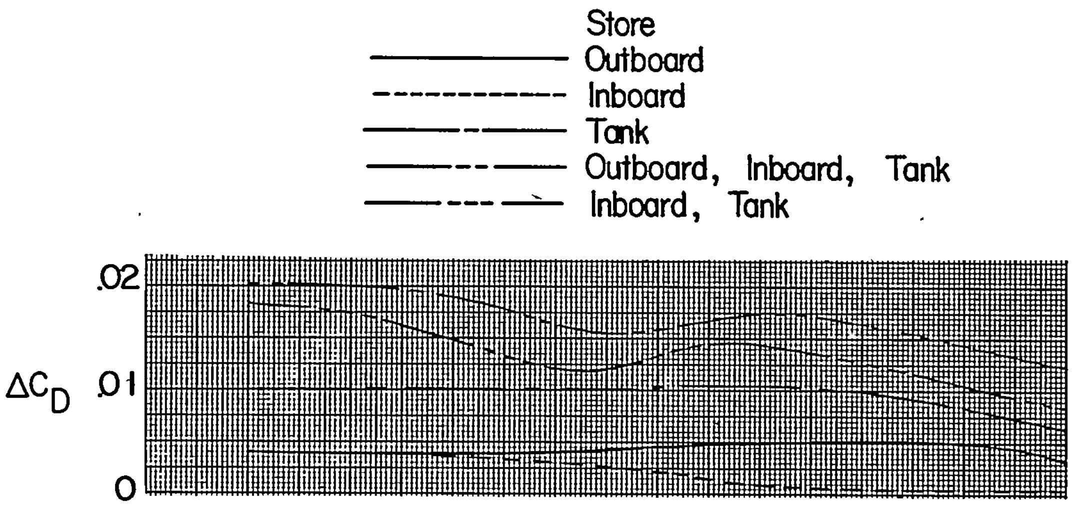
(b) $\alpha = 4^{\circ}$.

Figure 9.- Continued.

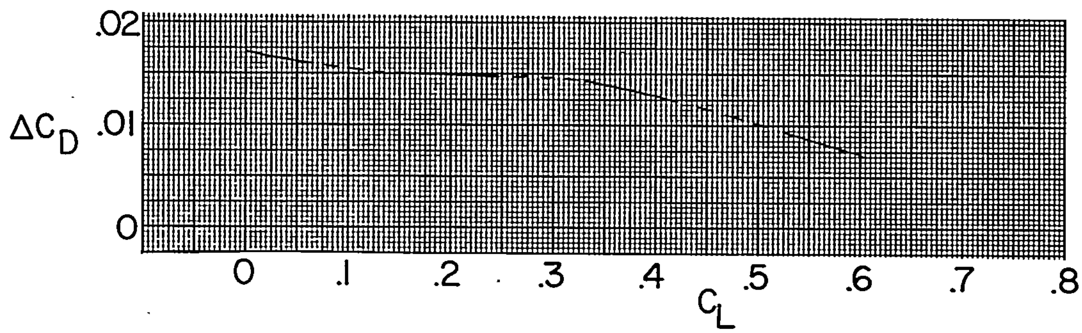


(c) $\alpha = 8^{\circ}$.

Figure 9.- Concluded.

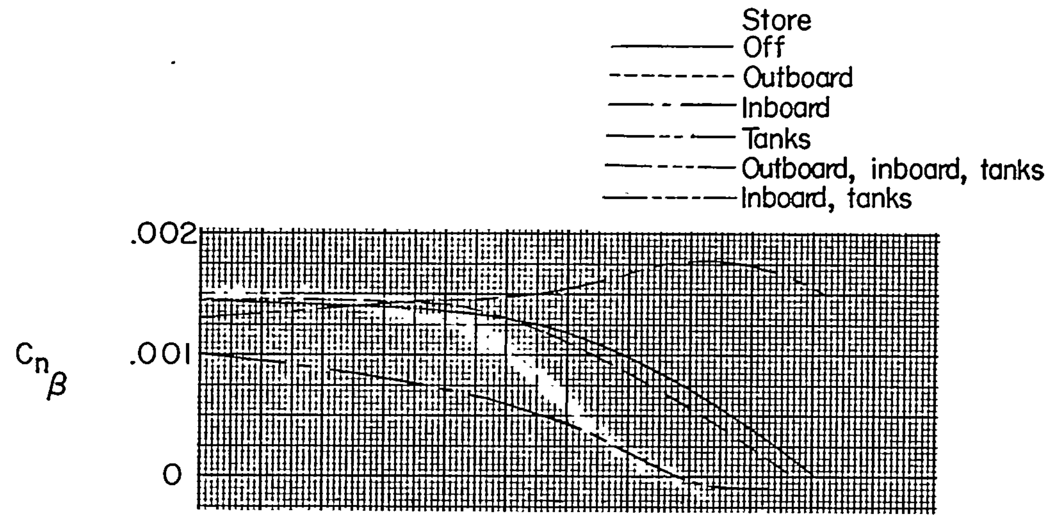


(a) Modified vertical tail; M = 1.61.

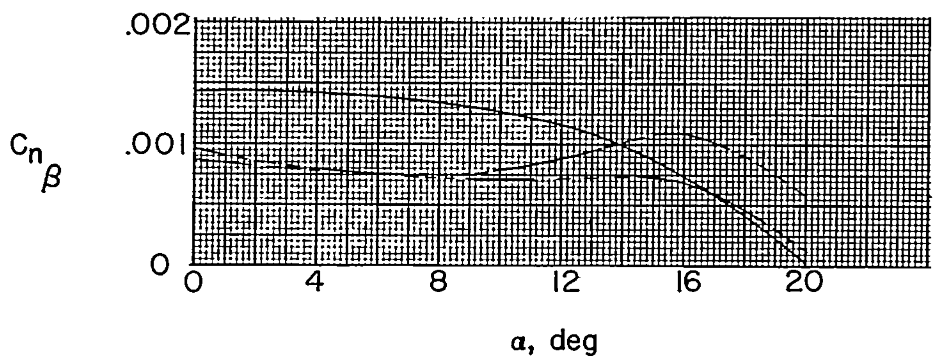


(b) Original vertical tail; M = 2.01.

Figure 10.- Incremental change in longitudinal-force coefficient due to various arrangements of the external stores on the complete model. $\beta = 0^{\circ}$.

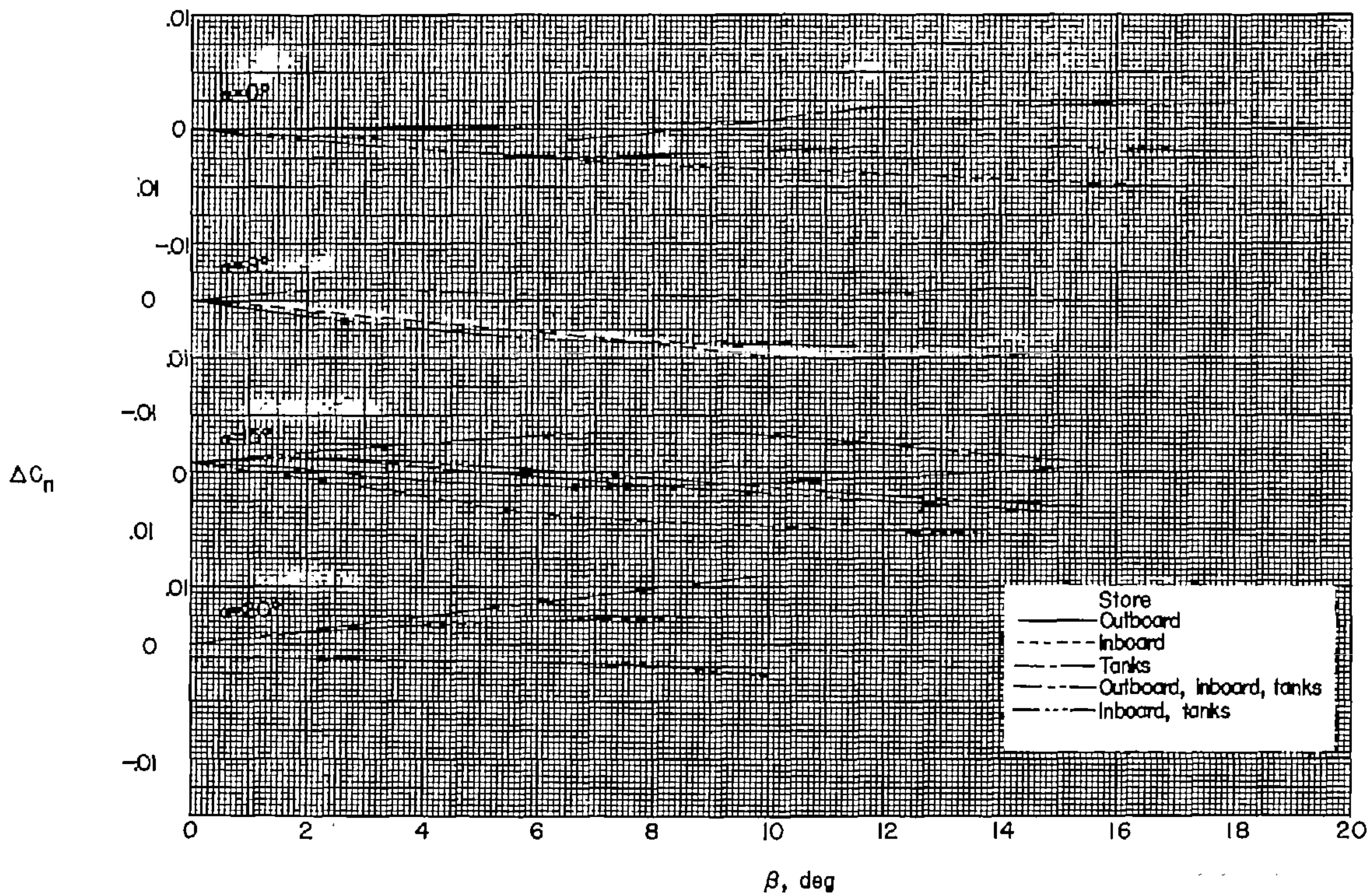


(a) Effect of individual stores.



(b) Effect of stores in combination.

Figure 11.- Effect of various store configurations on the variation of C_{n_β} with α. Modified vertical tail; M = 1.61.



(a) ΔC_n against β.

Figure 12.- Incremental change in C_n, C_Y, and C_l due to various arrangements of external stores on the complete model. Modified vertical tail; M = 1.61.

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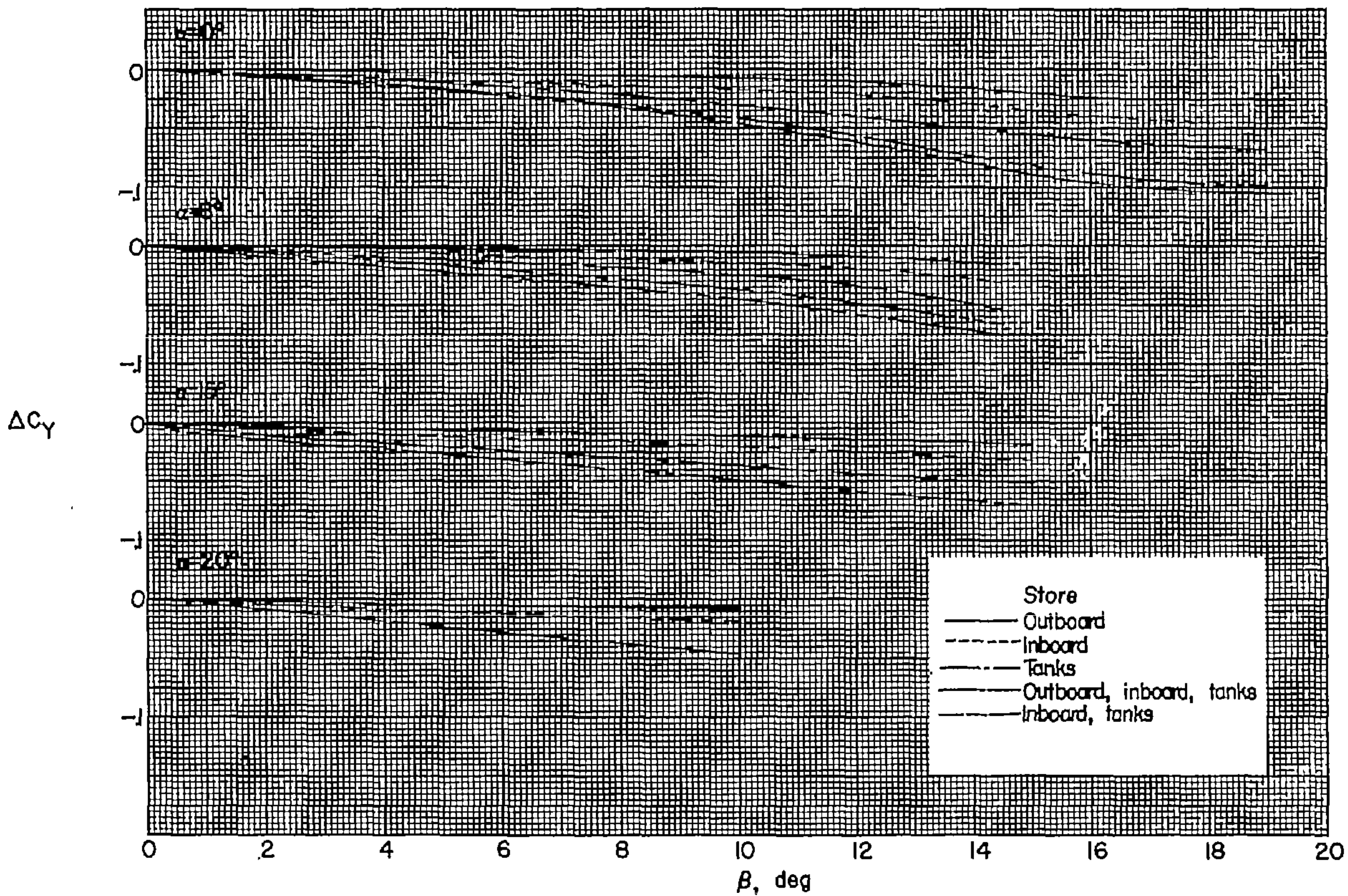
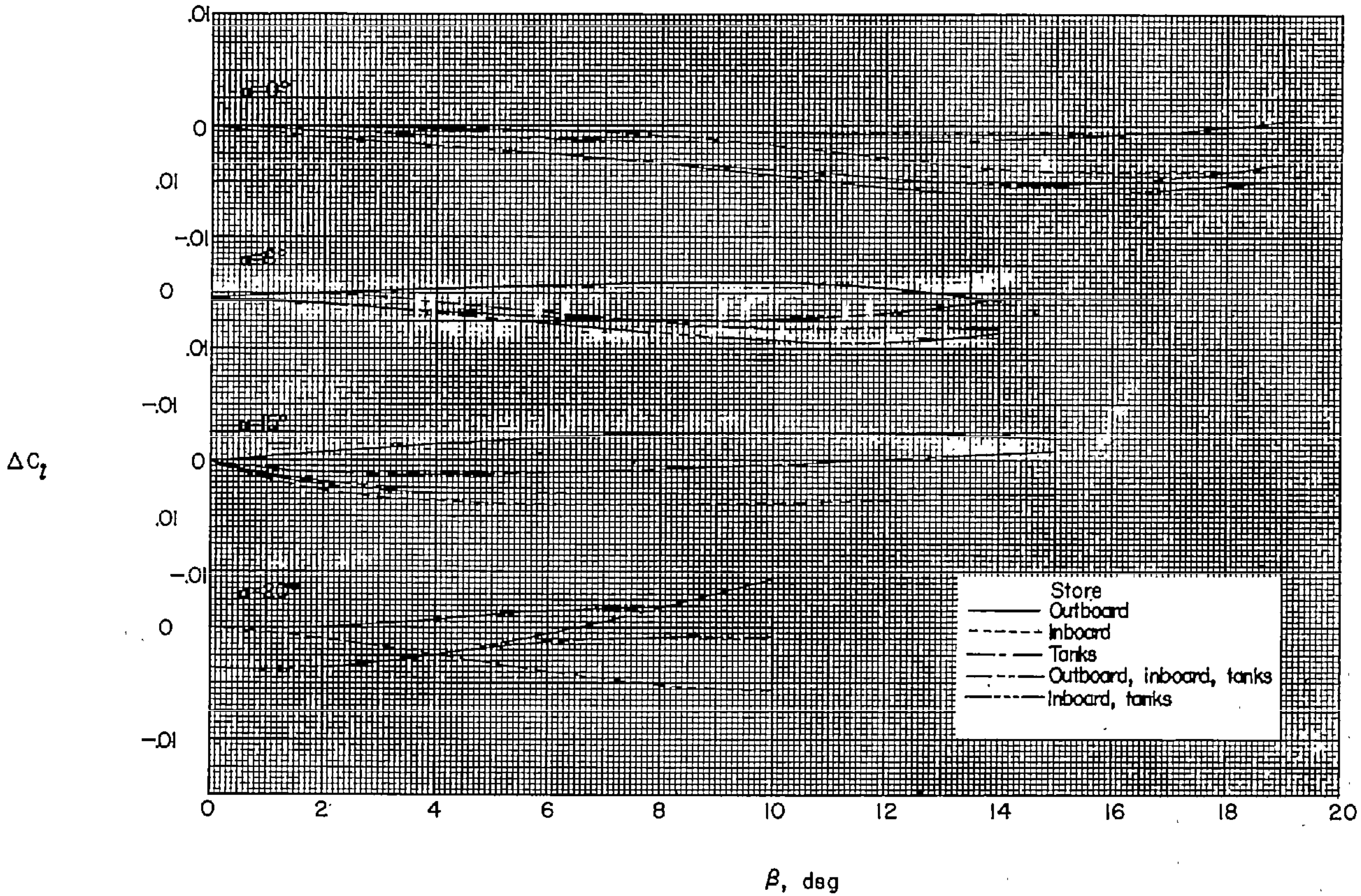


(b) ΔC_Y against β.

Figure 12.- Continued.

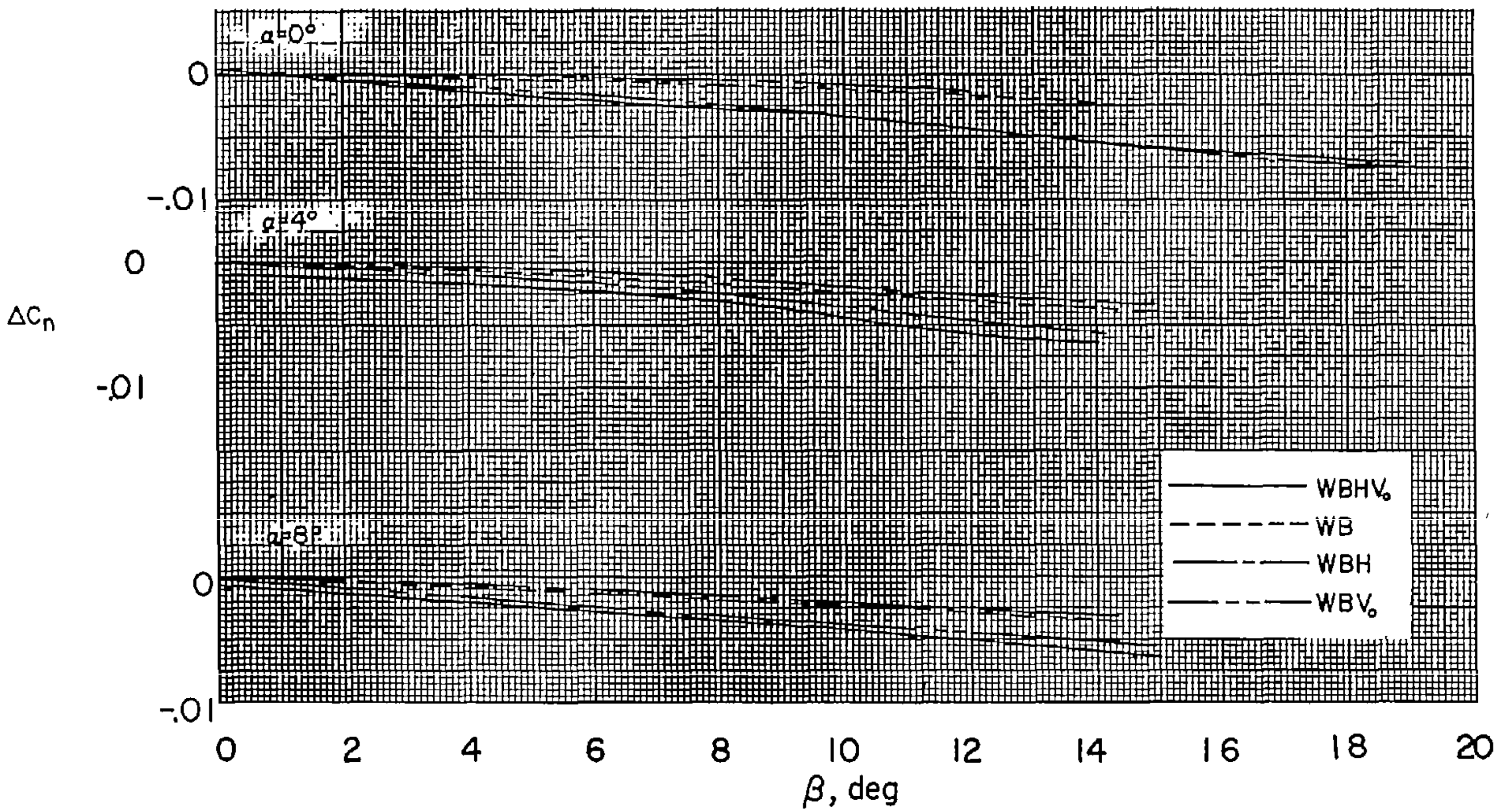
[redacted]



(c) ΔC_l against β.

Figure 12.- Concluded.

[redacted]



(a) ΔC_n against β.

Figure 13.- Incremental change in C_n, C_Y, and C_l due to inboard stores and tanks with various components of the tail removed. M = 2.01.

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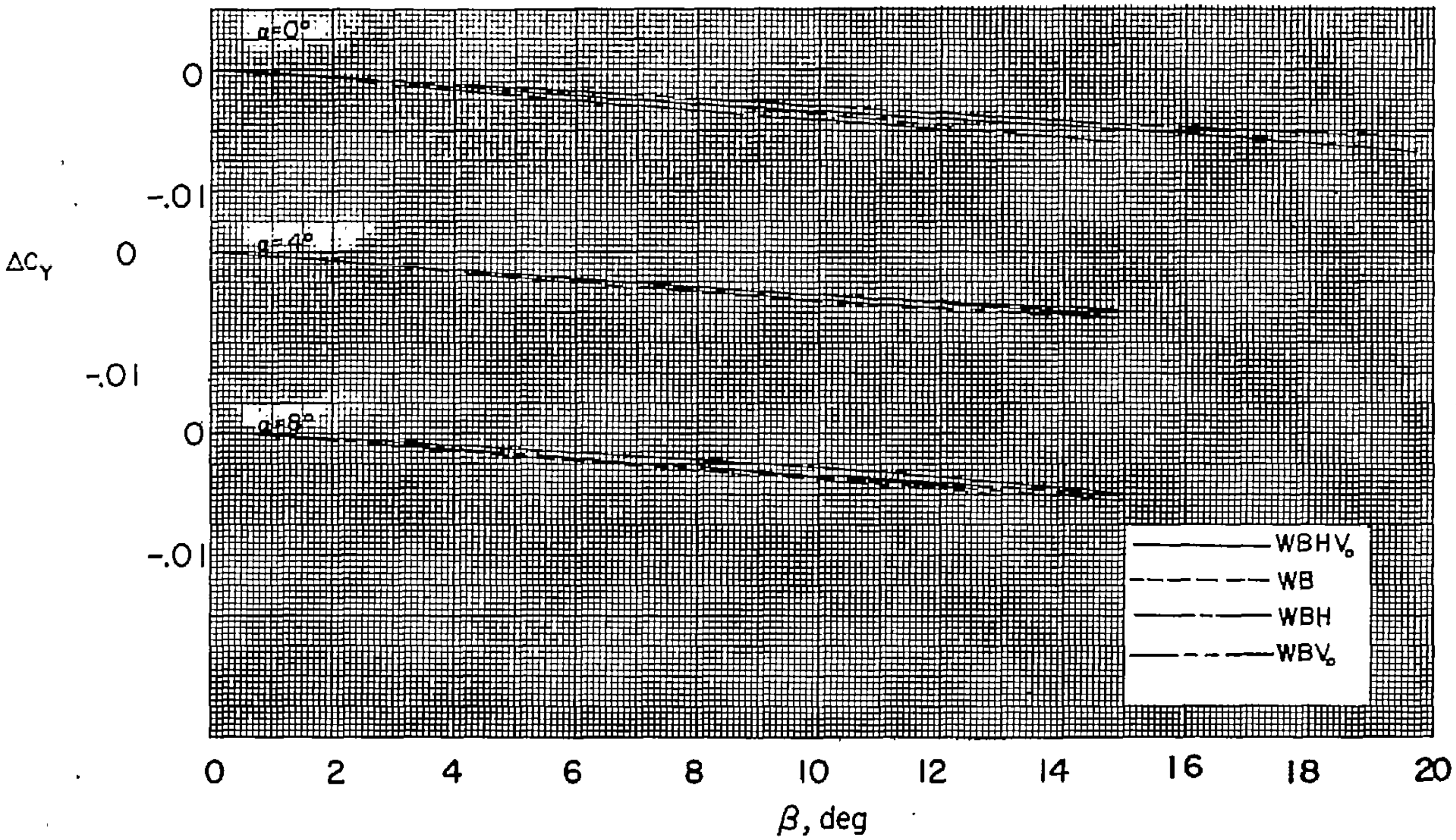
[redacted]



(b) ΔC_Y against β.

Figure 13.- Continued.

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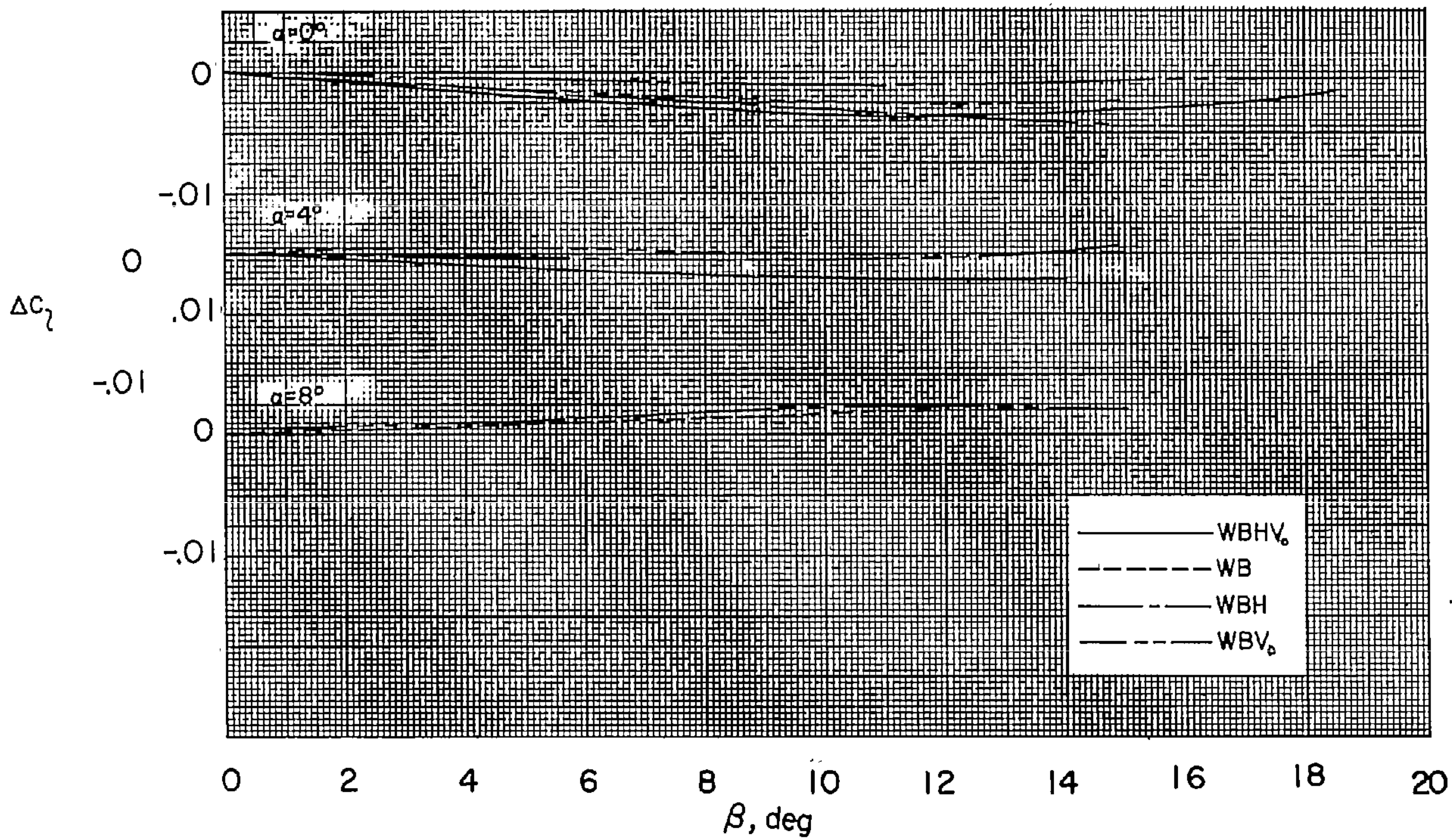

(c) ΔC_l against β.

Figure 13.- Concluded.